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NORTH ATLANTIC TREATY ORGANIZATION

RESEARCH AND TECHNOLOGY ORGANIZATION

BP 25, 7 RUE ANCELLE, F-92201 NEUILLY-SUR-SEINE CEDEX, FRANCE

RTO MEETING PROCEEDINGS 33

Operational Issues of Aging Crewmembers

(les Conséquences opérationnelles du vieillissement des équipages)

Papers presented at the RTO Human Factors and Medicine Panel (HFM) Symposium, held in Toulon, France, 11-14 October 1999.

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Operational Issues of Aging Crewmembers

(RTO MP-33)

Executive Summary

The Human Factors and Medicine (HFM) Panel held a Symposium on "Operational Issues of Aging Crewmembers" in Toulon, France, from 11 to 14 October 1999.

In many NATO countries, the populations in general are aging and military crewmembers are an increasingly older population. In downsizing militaries with scarce resources, the increasing costs of training and the significant experience (also at significant cost) of aging crewmembers make them an increasingly valued commodity, particularly as projected in the militaries of the future. Experience, wisdom, healthy lifestyles, and medical and technological advances seem to compensate to some extent for decreased performance and other adverse effects of aging (physical, physiological and psychological) in many crewmembers. Most "aging" studies have accumulated data on general civilian populations and data on the performance of aging crewmembers in military environments have not been previously summarized and presented on any large scale. Thus, the NATO HFM Symposium on "Operational Issues of Aging Crewmembers" was planned to present available data regarding whether or not healthy lifestyles, technological advances and compensatory factors of aging crewmembers, such as experience, adequately compensate for performance among various types of aging crewmembers (pilots, special crew, divers, etc.). If so, a re-evaluation of age policies for military crewmembers might be justified.

The Symposium was divided into 3 sessions to accommodate the various topics related to aging crewmembers working in various stressful military environments. In the Session "Operational Aspects of Aging Crewmembers", papers were presented on G tolerance, jet lag, spinal disease, ECG findings during centrifuge training, hypoxia tolerance and time of useful consciousness during hypobaric flights, and pulmonary function in divers. In the Session on "Aging Crewmembers: Psychological and Cognitive Performance Implications", there were presentations on sleep, wording memory, personality, behavior, fatigue, risk taking, safety and mission completion, psychological performance, cognitive and sensory limitations and neuropsychiatric referrals. During the final Session, on "Physiological and Sensory Aspects of Aging", papers were presented on anthrax immunization, growth hormone, endocrine responses to training programs, autonomic cardiovascular control, biochemical-metabolic indices, endothelial dysfunction, intima media thickness, cardiovascular risk factors, visual acuity, ocular problems, intraocular lenses, visual performance during small letter contrast tests and on modern cockpits.

While much of the available data on the effects of aging on human performance has been acquired from general populations, this Symposium provided data on the effects of aging on performance in crewmembers, not usually considered 'elderly', who live and work in stressful military operational environments (such as hypobaric, hyperbaric, high G forces, etc.), and frequently do so for prolonged periods. This data is particularly militarily relevant considering the increasing average age of populations (including military populations); the projected increasing costs of training and reduced resources and manpower in many militaries; and, therefore, the ever increasing value of healthy, experienced, aging crewmembers.

Significant conclusions that can be drawn from the data presented were three. (1) During these times of prevention, health promotion and healthy lifestyles, physiologic age of individuals seems to be more important than chronological age of groups. (2) Knowledge, behavior and experience seem to adequately compensate for aging among crewmembers in military environments. (3) The aforementioned, combined with new medical and surgical therapies and technological advances (in equipment designs, etc.), appear to justify seriously re-looking at current age policies for military crewmembers (particularly if, and when, a country's military manpower and budget projections deem it appropriate).

les Conséquences opérationnelles du vieillissement des équipages

(RTO MP-33)

Synthèse

La commission des facteurs humains et médecine (HFM), a organisé un symposium sur «Les conséquences opérationnelles du vieillissement des équipages» à Toulon, en France, du 11 au 14 octobre 1999.

De manière générale, les populations de bon nombre de pays de l'OTAN sont vieillissantes et l'âge moyen des équipages militaires est de plus en plus élevé. Dans une situation où il est nécessaire de réduire le personnel militaire à moindre coût, et où les coûts de formation ne cessent d'augmenter, l'expérience déjà acquise par les équipages vieillissants (dont le coût a également été considérable) fait que ce personnel est de plus en plus prisé, et est donc souvent pris en compte dans les prévisions des forces armées pour les années à venir. En effet, l'expérience, le bon sens, les habitudes saines de vie quotidienne et les progrès technologiques et médicaux semblent compenser dans une certaine mesure la diminution des performances et autres effets négatifs du vieillissement (physiques, physiologiques et psychologiques) pour la plupart des membres des équipages. Jusqu'à présent, la plupart des «études sur le vieillissement» ont porté sur des populations civiles, et les éventuelles données sur les performances des équipages vieillissants dans des environnements militaires n'ont jamais été synthétisées ni présentées de façon complète. Par conséquent, le symposium NATO HFM sur «Les conséquences opérationnelles du vieillissement des équipages» a été organisé dans le but de présenter les données disponibles sur cette question. Il s'agit de déterminer si les styles de vie équilibrés, les progrès technologiques et un certain nombre de facteurs de compensation chez les équipages vieillissants, tels que l'expérience, compensent de façon adéquate ou non la diminution des performances des différentes catégories de personnels navigants (pilotes, membres d'équipages, plongeurs etc..) Si tel est le cas, une réévaluation des politiques en matière d'âge pour les membres d'équipages militaires pourrait se justifier.

Le symposium a été réparti en trois sessions pour permettre l'examen des différents sujets se rapportant aux membres d'équipages vieillissants qui travaillent dans des environnements militaires stressants. Lors de la session sur «Les aspects opérationnels du vieillissement des équipages», des communications ont été présentées sur la tolérance aux accélérations, les effets du décalage horaire, les maladies de la moelle épinière, les résultats des électrocardiographies réalisées lors de séances d'entraînement en centrifugeuse, la tolérance à l'hypoxie, les durées de conscience utile en vol hypobare et sur la fonction pulmonaire chez les plongeurs. La session intitulée «Les membres d'équipages vieillissants: les conséquences pour les performances psychologiques et cognitives», a comporté des communications sur le sommeil, la mémoire auditive, la personnalité, le comportement, la fatigue, la prise de risques, la sécurité et l'achèvement de la mission, les performances psychologiques, les limites cognitives et sensorielles, et les renvois en neuropsychiatrie. Lors de la dernière session sur «Les aspects physiologiques et sensoriels du vieillissement», des communications ont été présentées sur l'immunisation contre l'anthrax, l'hormone de croissance, les réponses endocrines aux programmes d'entraînement, le contrôle cardio-vasculaire autonome, les indices biochimiques-métaboliques, le dysfonctionnement endothélial, l'épaisseur intima media, les facteurs de risque cardio-vasculaires, l'acuité visuelle, les problèmes oculaires, les lentilles intraoculaires, les performances visuelles lors de tests de contraste sur des lettres minuscules et le cockpit moderne.

A la différence de la plupart des études disponibles sur les effets du vieillissement sur les performances humaines, qui concernent les populations civiles, ce symposium a proposé des informations sur les effets du vieillissement sur les performances des membres d'équipages militaires, qui ne sont pas considérés normalement comme «des personnes âgées», qui vivent et qui travaillent dans des environnements opérationnels militaires stressants (environnements hypobares, hyperbares, accélérations élevées etc..) souvent pendant des périodes prolongées. Ces données ont une pertinence militaire particulière, eu égard à la progression de la moyenne d'âge des populations (y compris dans les populations militaires), à la croissance prévue des coûts d'entraînement, à la diminution des moyens financiers et du personnel que connaissent beaucoup de forces armées, et, par conséquent, à l'intérêt croissant de disposer de membres d'équipages vieillissants, expérimentés et en bonne santé.

Trois conclusions importantes ont pu être tirées des données présentées, à savoir: (1) A cette époque où l'accent est mis sur la prévention, la promotion de la santé et les habitudes de vie saine, l'âge physiologique d'un individu semblerait être plus important que l'âge chronologique d'un groupe. (2) Les connaissances, le comportement et l'expérience sembleraient largement compenser le vieillissement des membres d'équipages militaires. (3) Ce qui précède, combiné avec les nouvelles thérapies médicales et chirurgicales et les avancées technologiques (conception des équipements etc..) semble largement justifier le réexamen des politiques actuelles en matière d'âge des membres d'équipages militaires (en particulier si les prévisions en matière de budget et de personnels militaires d'un pays le rendent opportun).

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TECHNICAL EVALUATION REPORT

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1. INTRODUCTION

In many NATO countries, the populations in general are aging and military crewmembers are an increasingly older population. In downsizing militaries with scarce resources, the increasing costs of training and the significant experience (also at significant cost) of aging crewmembers makes them an increasingly valued commodity, particularly in militaries of the future. Experience, wisdom, healthy lifestyles and medical and technological advances seem to compensate to some extent for decreased performance and other adverse effects of aging (physical, physiological, psychological) in many crewmembers. Most "aging" studies and data, however, are on general (civilian) populations. Available data on the performance of aging crewmembers in military environments have not been previously summarized and presented on any large scale. As a result, the NATO Human Factors and Medicine Symposium on "Operational Issues of Aging Crew Members" was planned and military age policies (pilots, special crew, etc.) of several countries were collected in advance for presentation and discussion. The Symposium was finally held at the Institut de Medicine Navale du Service de Sante des Armees, Toulon, France, from 11 – 14 October 1999. Of the 35 papers scheduled, 32 were presented along with two keynote addresses. Eleven NATO nations contributed to the main program. There were 120 registrants for the Symposium.

2. THEME

Military crewmembers have a limited operational lifetime during which their capacity to perform their missions can be considered as adequate. Aging s seen as an irreversible process whose development is characterized by progressive loss of physical and physiologic functions, which in operational crews can mean increased difficulty in coping with the specific demands of their assignments. On the other hand, the increasing knowledge and expertise attained in some instances may compensate or even overcome declining age-related performance. The capacity of different crewmembers to withstand stress and unforeseen events must be evaluated, taking into account the fact that the normal aging process may also be accelerated by prolonged exposure to mission environments.

The term aging is equated by most authors with senescence, and consequently there are few studies devoted to the effects of aging during the early and middle decades of the life span.

Papers were solicited to address our knowledge of the effects of aging on military crews members, to compile data from different Armed Forces medical institutes and other laboratories regarding the performance of different age groups of crews exposed to specific military operational environments. In addition, papers were solicited to address the present lack of information on the repercussions of the prolonged repetition of certain missions over the years on aircrew health, including mission-related disorders and the early appearance of age-related diseases.

3. PURPOSE AND SCOPE

The Purpose of this symposium was to review data, if any, regarding age restrictions on certain types of crew operations; to review the data on the impact of age on crew performance in operational environments; to review the novel and emerging medical therapies and technological aids that impact or might impact on aging crew members; to determine to what extent increased knowledge, expertise and experience can ameliorate the impacts of aging; to consider the impact of healthy lifestyles and preventive measures on aging; and to finally determine if current age restrictions on certain types of crew operations should be seriously re-evaluated for change.

In many NATO countries, military crewmembers are an increasingly older population, particularly in downsizing militaries with scarce resources. Because of their training and experience, these aging crewmembers are frequently able to compensate for their age and are becoming an increasingly valuable commodity. At the same time, advances in technologies have helped overcome some of the difficulties (visual, hearing, strength requirements, etc.) experienced in aging crews. In addition, due to healthier lifestyles and medical

advances in prevention and therapies, many of these aging crewmembers are physiologically significantly younger than their chronological age. Restricting certain types of military operations to crewmembers solely on the basis of age may not be the best use of increasingly valuable, well-trained, experienced, "chronologically young" crewmembers in the 21st century.

4. SYMPOSIUM PROGRAM

The Symposium, co-chaired by Ltcol C. Alonzo-Rodriguez (SP) and Medecin en Chef D. LaGarde (FR), consisted of two keynote addresses, Keynote Address I, "Aging Crewmembers: Physiological and Operational Considerations", presented by LtCol C. Alonso-Rodrigues, Hospital del Aire, Madrid, Spain; and Keynote Address II, "Human Factors Considerations of Aging Crew Members: an Overview", presented by Prof. T. Dobie, Director, National Biodynamics Laboratory, University of New Orleans (New Orleans, LA), USA. Keynote addresses were followed by 3 Scientific Sessions as follows:

A. Session I. Operational Aspects of Aging Crew Members, chaired by Med. En Chef D. LaGarde (FR) and Col. W. Tielemans (NE), was addressed in 12 presentations.
B. Session II. Ageing Crewmembers: Psychological and Cognitive Performance Implications, chaired by Col D. Salisbury (CA) and Maj. F. Rios-Tejada (SP), was addressed in 8 presentations.
C. Session III. Physiological and Sensory Aspects of Aging, chaired by LtCol C. Alonso-Rodrigues (SP) and Capt (Navy) R. Hibbs (US), was addressed in 12 papers.

5. TECHNICAL EVALUATION

In the first Keynote Address, "Aging Crewmembers: Physiological and Operational Considerations", LtCol C. Alonzo-Rodriguez (SP) discussed the pathophysiological mechanisms of aging and delineated the various age policies for crewmembers in 21 NATO and other European countries. He then discussed medical reasons for and against setting specific crew member retirement ages, the impact of specific missions and operational stresses on aging crew members, and the impact of preventive measures, therapeutic measures, healthy lifestyles the environment and other factors on the aging process. The presentation summarized the associated paper, which was a very extensive overview citing 55 references.

In the second Keynote Address, "The Human Factors Considerations of Aging Crew Members, Prof. T. Dobie (US) discussed the arbitrary age limits set by certain employers, the importance of being "fit" enough (as opposed to young enough) for a specific job, and stereotypes of performance and frustrations encountered by older personnel. He followed with discussion on the roles of experience and motivation in performance, and that we are dealing with individuals, with varying levels of physiological age and performance, for whom group arbitrary age criteria are probably not valid. Considering the above and the heavy investment in the older, experienced and competently performing crew members, a longitudinal study using data from physical examinations and other measures health and performance would yield valuable data to help us more effectively deal with the issue of aging and crewmembers.

SESSION I. OPERATIONAL ASPECTS OF AGING CREW MEMBERS

This session addressed the impacts of G tolerance, jet lag, spinal disease, hypoxia tolerance, pulmonary function and other medical and physiological aspects of aging crew members working in stressful operational environments.

The first paper, "The Effects of Aircrew Age on +Gz Tolerance as Measured in a Human-Use Centrifuge", was presented by Dr. E.M. Forster, who discussed acceleration training data obtained by the Naval Air Warfare Center in Warminster, PA, as part of the G Tolerance Improvement Program. Data acquired on 1120 air crew (74% pilots), 95% of whom were crew in high performance aircraft, did not show a significant effect of age (20-61 years) on tolerance to gradual and rapid onset +Gz exposures measured in the human centrifuge.

Paper # 2 being cancelled, Dr. Didier Lagarde presented paper #3, "Evaluation of the Effect of Crew Members Aging on Jet Lag Consequences", after showing a film on the comparison of 300mg slow release caffeine, 5mg melatonin and placebo on 28 aircrew after a 7 hour transmeridian flight during "Pegasus Operation". He discussed only the placebo group (6 men, 3 women), noting that the veteran crew members (six subjects >35 years old) had a better subjective feeling of well-being with a small decrease in vigilance in the evening, compared to younger, less experienced crew members (3 subjects) who had higher flicker fusion scores. Also, the veterans (older group) had a lower orthostatic heart rate, showing better cardiovascular adaptation than the younger groups. He also noted that attention, strength, melatonin and cortisol levels in saliva samples, and other physical performance and alertness measures showed no significant change with age. He concluded that age seemed to have a weak affect on subjects' vigilance, and that veterans, maybe because of their experience, weren't affected by jet lag. However, he noted that some parameters, such orthostatic heart rate or the modified sleep parameters needed additional attention.

Prof. J.A.F. Tresguerres presented paper #4 "Age Dependent Alterations Induced by Transmeridien Flights in Airline Pilots". Comparing older (>50 years) and younger pilots among two groups, one traveling East (Madrid-Tokyo-Madrid) and the other West (Madrid-Mexico-Madrid in Iberian Airlines 747s, his data showed that there was no significant change in blood

pressure or tiredness and that the older pilots revealed less anxiety than the younger pilots. However, his data also showed a decrease in performance scores among the older pilots compared to younger pilots.

Mr. Pierre J.C. Valk presented paper #5 "Influence of Age on Alertness and Performance during 3-Day Cross-Atlantic Operations". He compared general functions such as attention, concentration and information processing speed; specific cognitive functions such as in-flight tasks, perception, memory, problem solving and decision making; psychomotor coordination (on flight controls), psychological (anxiety and fatigue) tests, urine excretion of cortisol, skin temperature and heart rate rhythms among younger (<40 years old) and older male pilots There was no significant difference noted between the younger and older groups in locomotor activity, skin temperature recordings or heart rate rhythms. Older pilots exhibited lower excretory values, lower levels of anxiety and less improvement in the execution of attention-perception tasks than younger pilots. In summary, he noted that there was significant difference between the groups with respect to % omissions in the vigilance test (higher among older pilots), and tracking performance (older pilots performed worse), but not with respect to alertness, sleep quality, sleep latency, total sleep time. In addition, the sleep quantity and quality during stopover (night) were sufficient to allow older pilots to recover and perform at an adequate level on the return flight.

Dr. William E. Drew presented paper #6 "Spinal Disease in Aviators and its Relationship to G-Exposure, Age, Aircraft Seating Angle, Exercise and Other Lifestyle Factors". Using survey methodology, he compared acute and chronic spinal disease symptoms among aircrew in High Performance (HP) aircraft compared to those in non-high performance aircraft. Mean age was similar in both groups. Within both groups, there was no significant difference in neck pain nor significant worsening of neck pain with age but there was a slight upward trend (limited power of study). There was no greater incidence of chronic spinal symptoms or disease in the neck and lower back reported in HP aircraft air crew, but HP air crew did report acute spinal symptoms, especially in the neck and temporally associated with pulling G's. These acute symptoms frequently limited their flying performance, but were self-limited and did not appear to result in any increase in long-term morbidity or accelerate degenerative symptoms.

Paper #7 "Degenerative Changes of the Spine of Fighter Pilots of the RNLAF" was presented by Mr. M. Holewijn and discussed whether F-16 pilots (188) were at increased risk of (cervical) spine degeneration compared to 128 controls (other pilots). All (316) pilots of the RNLAF were systematically radiographed at lease twice between 1982 and 1994 and two 'blinded" radiologists examined the X-rays separately. Analyses were also performed on a subgroup (101 F-16 pilots and 67 controls) to obtain a statistical equal mean age in the two groups. Although the inter-rater agreement of X-ray interpretation was low, retrospective analysis showed that both radiologists found significant differences between the age groups at several levels of the spine. Increased osteophytic spurring was found at levels C4-5 and C6-7 and increased arthrosis deformans were found among F-16 pilots compared to controls, suggesting that frequent exposure to high +G forces might cause premature degeneration of the spine.

LCOL T. Pippig presented paper #8 "Prevalence of Cervical and Lumbar Disorders of Pilots of the German Armed Forces". Among 3000 aircrew retrospectively examined, he presented data on 349 aircrew (including 286 pilots) who had spinal pain, including helo, jet and transport jet pilots. Among aircrew examined, 70% were symptomatic for spinal disease, including 100% of the pilots. Lumbar symptoms were noted in 223 pilots and cervical symptoms in 63, and 24% of the pilots had received surgical Rx for C5-7 or L4-S1 disease. Only a small % of the control group (123 ATC personnel) had spinal symptoms, suggesting an increased risk of symptomatic spinal disease among pilots compared to non-pilots.

Paper #9 "ECG Findings during Centrifuge Training in Different Age Groups of Turkish Air Force Pilots" was presented by Dr. M. Alan. In a retrospective study of all 486 pilots who underwent centrifuge training during the past 2 years, he compared two age groups, 22-30 years old (N=398) and 31-42 (N=88). Analysis of Rapid Onset Run Profiles, dysrhythmias were recorded in 29.4% of all pilots, most commonly premature ventricular contractions. Dysrhythmias were significantly higher in the older group (36%), however, than the younger group (17.7%) during exposure to 8-9 Gs.

Col M.G. Braithwaite presented paper #10 "Territorial Army Aircrew – 'The Senior Pilots': Are They at Greater Risk?". Territorial Army (TA) pilots have generally retired from regular service, although some fly commercially, and are a special risk occupation due to their "solo operations". Comparing medical records of Regular Army (614, mean age 34) and Territorial Army (89, mean age 44) who had been medically downgraded to lower flight categories, the authors found that the most common causes were orthopedic (primarily back, peak age 36-40), cardiac (arrhythmias) and decreased visual acuity. Only 19 of the TA pilots had been grounded, most for minor, waiverable conditions, and 12 had no restrictions on flying medical category. Looking at accidents, there was a decreased accident rate with increasing age, the young pilots 12 times as likely to be involved in an accident as older pilots and there were no accidents among those over 51 years old. Two-thirds of the accidents were reportedly caused by Human Factors. There was no evidence that the age of operational pilots should be reduced for operational reasons. Senior pilots were not found at greater risk. On the contrary, due to self-selection and being well attended by their flight surgeons, older TA pilots were found both safer and less of a burden on medical services.

Paper #11 "Age Factor Related to Hypoxia Tolerance" was presented by Capt. P. Vallejo. Authors selected randomly and retrospectively 161 subjects (54 flyers, 62 parachutists and 45 non-flyers) who qualified for and flew in the Hypobaric Chamber between 1993 and 1999. Various factors were looked at, including age, BMI and smoking. Authors noted an increased weight and prevalence of smoking with age. Comparing 3 age groups (20-29, 30-39 and 40+), the authors found an increased reaction speed among younger group (usually first timers). Interestingly, they found an even faster time among the middle group (usually second timers through the chamber) than among either the younger or the older group, concluding that those aged 30-39 tolerated hypoxia better than the other age groups.

Ltcol Nuno Rubeiro presented paper #12 "Time of Useful Consciousness in Crewmembers During Hypobaric Chamber Flights", and reported data on time of useful consciousness (when oxygen mask was removed) among 43 Portugese Air Force military personnel (36 males, 7 females, age 25-44) during hypobaric chamber training, and although numbers studied were small, found no significant difference between hypoxia times and age or smoking habits.

Paper #13 "Pulmonary Function in a Diving Population Aged over 40 Years Old: A Cross-Sectional Study" was presented by Capt Olea Gonzalez. Authors studied 23 divers (mean age 44, including 8 smokers) and looked at diving depth reached, fitness, smoking, and accidents using a questionnaire and studied pulmonary function tests. They found no significant difference in pulmonary function between smokers and non-smokers, but all parameters were higher (trends) in those most fit. The authors concluded that older age divers have larger lung capacities than normal populations, that smoking and sports weren't significantly related to pulmonary function, but maximum depth reached and the number of years diving experience are significantly related to pulmonary function.

SESSION II. AGING CREWMEMBERS: PSYCHOLOGICAL AND COGNITIVE PERFORMANCE IMPLICATIONS

This session addressed the impact of age and neuropsychiatric referrals on sleep, working memory, personality and behavior. The first paper in this session, paper # 14 "Sleep and Age: From Physiology to Therapeutics" was presented by Dr. Didier Lagarde, wherein he summarized the current knowledge and therapies for sleep recovery. He and his colleagues showed that physiologic sleep disturbances appear after 35 years of age, and after ages 40-50, sleepiness and symptoms appear earlier with a reduction in diurnal vigilance, which can adversely impact on operational performance (the people becoming more "morning" people). With increasing age there is decreased secretion of melatonin. He described both non-pharmacologic compensatory factors, such as behavior, and pharmacologic therapies such as melatonin, slow release caffeine, modafinil and benzodiazepine hypnotics. They concluded that there is a decreased restoring effect of sleep deprivation as early as age 45, which can be effectively treated up to age 60 with psychostimulants and hypnotics to ensure, without side effects, adequate vigilance and performance.

The next paper, #15, entitled " Working Memory, Age, Crew Downsizing, System Design and Training", was presented by Dr. M.J. Cook, who began by describing working memory and the impact of fatigue related to the decreasing size of aircrews the increasing working memory workload. He noted that working memory, the ability to store information on a short-term basis for rapid retrieval or to retain cues to aid recall of long-term information, is often presented as a major bottleneck in human performance. The rate-limiting step is the duration of central processing (information that must be converted to knowledge). Working memory has been shown to be predictive of capability and is used in selection tests. Fatigue, stress, time of day and age decrease the capacity of working memory. They noted that with aging, there is a decreased speed and reduced quality of transfer of working memory to sensory memory, so the capability to acquire and integrate new information is reduced. With increased age, there is a decreased ability to manipulate information into working memory, decreased central execution function, increased distraction and decreased recovery from stress, fatigue and jet lag. There is some compensation from experience, particularly greater training at an early age. In summary, as aircrew size decreases, working memory load increases, and as aircrews age, their ability to manipulate information decreases and, beyond a certain point, this could become a recipe for disaster.

In paper # 16, "Aging and Risk Taking in the Navy", B. Sicard and colleagues studied the effects of naval crew aging on risk proneness using the EVAR test (a visual analogue scale designed to rate risk proneness) on 130 male navy personnel, ages 19-41 years. The EVAR test is designed to measure factors of self-control, danger seeking, energy and impulsiveness. Younger aircrew scored much higher on all scores of thrill seeking (lower scores among females). They observed a positive correlation with age and self-assurance and managing (lead vs. follow), although the results were not significantly different. The only significant correlation was a negative correlation between "energy" and aging. They concluded that change in risk proneness (and decision making and safety) among 19-41 year old aircrew is not significant, but the decrements in "energy" observed with aging, implying a decreased coping response, could impact on sleep deprivation and performance during certain work schedules (such as night shift).

"The Cost/Benefit of Aging on Safety and Mission completion in Aviation Professions" was paper #17, presented by R.E, King. During a study supported by the Defense Women's Health Research Program, they tested intelligence quotients of 46 USAF female pilots (mean age 30) and 64 male USAF

pilots (mean age 29). They found superior intelligence levels and, compared to the general population, standard deviations suggested that the pilots were a homogeneous group. The paper then addressed the improvement in performance in pilots with experience, the fact that age waivers were mostly (98%) approved, that military pilots who flew with the guard or Reserves had no upper age limit on flying duties. They also cited studies that indicated that while some cognitive abilities in older pilots may be compensated by experience, *individual* differences tended to be greater than differences between young and older pilots, and the benefits of increased experience (such as automaticity) may become overwhelmed during emergency and non-routine situations. In an older (mid 60s) pilot, neuropsychological impairment is unlikely to result in sudden incapacitation (as might a cardiac incident), but senses, memory, reaction time and ability to combat fatigue are likely to show the greatest decline. With increasing automation, requirements for pilot attitude are shifting from traditional "stick and rudder" to interpersonal programming and monitoring skills. Having reviewed several studies, author concludes that as fatigue is a greater risk factor for older aviators, regardless of experience level, "specific assessment using sensitive instruments will increase safety and mission completion".

Paper #18 "Pilots Memory and Psychological Performance Evaluation in Relation to Age", presented by J.P. Taillemite, discussed results of an evaluation of the relationship between age and aviation related tasks on performance. They tested 31 military and 69 commercial pilots in 3 age groups ranging from 23-59 years old, on SEPIA, a motion based psychomotor evaluation device similar to a flight simulator but with additional tasks such as mental arithmetic and visual discrimination tasks to distract from flying. At the end, pilots self-assessed their own performance. A significant negative correlation was observed between age (at 41 and beyond, but beginning early in the third decade) and working memory and psychomotor performance which were not influenced by type of training and experience.

Dr. J.B.J. Riersma discussed "Cognitive and Sensory Limitations with Aging", paper #19, realizing that with the graying population, training and education has to be compatible with the sensory and cognitive changes with age. The aging population uses many compensatory mechanisms to offset sensory and cognitive limitations, relying more on pattern recognition and specialized procedural knowledge, but must have the opportunity to update their skills and competencies by regular additional training and education in a fast changing world. Despite the functional limitations of the aging population, however, the authors conclude that in general no performance decrement in actual work is found.

Capt. B. Dones presented paper #20 "Effects of Age on Fighter Pilot Personality and Behaviour Parameters" (authored by Karaminas, Liatsos and Chimonas). They studied results of the Greek version of 16PF Form A, normally given to all pilots every three years, administered to 261 fighter pilots ranging in age from 23-41 years old. They noted a significant tendency for older pilots (>30 years old) to score lower on concrete vs. abstract thinking and sober vs. enthusiastic, and higher on low vs. high superego strength and on the reliability scale (low vs. high # of random responses during test taking). They concluded from these test results that there seems to be a tendency for fighter pilots to lose their motivation with age and that fighter pilots tend to turn more to themselves with age, becoming more silent, concerned, harder to communicate with and somewhat cautious and slow. Oh the other hand, older fighter pilots showed an increase in responsibility, determination, conscientiousness and rule acceptance.

"Neuropsychiatric Aeromedical Referrals: Do Trends Vary with Age?", paper #21, was presented by Maj. Daniel Orme. The authors examined 481 records of aviators evaluated during a 6 year period at the Neuropsychiatric Branch of the USAF Aeromedical Consultation Service. Records of aviators studied were divided into 3 age groups (20-29, 30-39, and 40-49 years old) and included only those less than 50 years old. Sixteen psychiatric diagnoses were represented in the sample, most commonly (more than two thirds) 5 diagnoses and 3 diagnoses representing relatively mild, non-disabling reactive disorders. However, these disorders can be dangerous in occupations requiring rapid information processing and higher order cognitive skills as in military flying. Analysis indicated that psychiatric diagnoses were not distributed evenly nor randomly across age groups, and that younger aviators were significantly less likely to be seen for evaluation than older aviators. The probability of receiving a psychiatric diagnosis significantly increases with age.

SESSION III. PHYSIOLOGICAL AND SENSORY ASPECTS OF AGING

Moving beyond the psychological and cognitive performance implications with age, this session dealt with the far more studied physiologic and sensory aspects of aging. The first paper, #22 "Anthrax Immunization in the Older Warrior", was presented by the sole author, LtCol M.J. World. Due to the higher than expected prevalence of adverse reactions following the first immunization, it was decided to monitor acceptance, adverse reactions, incapacitation and antibody responses in 129 members of a military field hospital during a voluntary program of anthrax immunization at 0, 3, 6, 24 and 32 weeks. IgG antibody levels (although not antibodies to protective antigens) were higher in immune personnel (immunized 7 years previously) and were not correlated with age. Adverse reactions (47% local, 24% systemic and 27% both) were not reported more frequently at any particular stage nor with increasing age. Increased reactions were reported among those who received anthrax immunization 7 years previously, or who were officers who experienced adverse reactions after the first immunization (not explained by age). Among older groups

who reported a previous adverse reaction occurred following the first immunization, however, there was a significantly higher risk of incapacity (inability to lift or drive, lasting 48 hours in the majority and no longer than 5 days).

Prof. J.A.F. Tresguerres presented paper #23 "Growth Hormone and Aging", wherein he reviewed the current knowledge on this topic and mentions experimental studies in his laboratory on growth hormone therapy in older rats, showing beneficial results as seen in humans. Growth hormone is pulsatile being excreted primarily during slow wave sleep. With age, there is a decrease in growth hormone, along with a decrease in sleep and melatonin. Decreased growth hormone in men >60 years old is responsible for decreased lean mass, increased adipose tissue and thin skin. Growth hormone treatment in the elderly has been shown to increase muscle volume and decrease fat volume (increase lipolysis), and increase heart rate, left ventricular mass and ejection fraction. With growth hormone therapy in the elderly, there is also a significantly increased exercise capacity (nearly 50%), significantly decreased ratio of LDL to HDL (decreasing cardiovascular risk), increased calcium absorbsion, increased bone healing and an increased immune response. However, growth hormone therapy is expensive. Finally, the author discusses the importance of determining whether or not growth hormone therapy should be seriously considered for those >60 years old.

In paper #24, Prof. C.Y. Guezennec presents "Endocrine Responses to Training Programs in Midlife". He discusses two hypotheses related to aging: programmed aging or the pacemaker hypothesis and the hormonal aging process. He, too, discusses the association of aging with decreased growth hormone, decreased gonadal secretion of steroids, decreased insulin sensitivity and decreased catecholamines. With exercise training, there increase in all classes of leukocytes (including immunocompetent cells except with long-term exercise). Exercise also increases levels of catecholamines resulting in a decrease in insulin (insulin sensitivity) and an increase in glucagon, and increases the levels of growth hormone, glucocorticoids, and testosterone (with short periods of training; a decrease with over training). Comparison of older joggers with younger has shown increased glucose levels in both and fewer insulin peaks in the older. (Rat experiments have showed the increased capacity of muscle to capture glucose.) In conclusion, physical training was shown to be strongly related to increased insulin sensitivity, increased sympathetic tone and increased lipid balance, but there is a negative effect on the immune system associated with intense training.

"Age Effect on Autonomic Cardiovascular control on Pilots", paper #25, was presented by Dr. R. Nikolova. Autonomic cardiovascular control was studied in 66 military pilots and in 39 age-matched controls, both groups aged 20-55 years old. Heart rate variability (HRV) and some HRV-derived indices were studied. The activity of both ANS branches was found to decline with age, and sympathetic activity declined more slowly than parasympathetic. Since age-desynchronized autonomic cardiovascular control was found only in military pilots but not in controls, it was concluded that the aging process in pilots is accelerated, presumably due to repetitive and prolonged exposure to stress, caused by compulsory underload (substantial reduction of flying tasks and physical exercises).

Paper #26 "the Association Between Aging and Biochemical-Metabolic Indexes in a Random Personnel Sampling of Hellenic Air Force", was presented by Lt. J. Markou. The authors studied a random selection of 539 adults (including 20 women) who were non-flying personnel of the Hellenic Air Force, ranging from 21-55 years old and divided into 5-year groups and in smoker and non-smoker groups. Data were derived from the complete medical examinations non-flight personnel must complete every 2 years. Associations were determined using linear regression analysis. Many physical, behavioral and laboratory results were compared. Results showed a positive statistically significant association between age and alcohol (in smokers), BMI, total cholesterol/HDL, total cholesterol, triglycerides, HDL (non-smokers), LDL, apoA, apoB, fibrinogen (smokers), potassium (smokers), urea (smokers) and glucose. There was a negative statistically significant association between age and exercise, and no association between age and smoking, Lp(a), SGOT, SGPT, bilirubin, sodium, creatinine and CRP.

"Does Aging or Endothelial Dysfunction Pose a Threat to Military Crewmembers?", paper #27, was presented by the author M.A. Rada. He described and cited studies regarding aging, particularly cellular changes due to an increased oxidative stress and/or to an impaired release of vasoactive mediators by endothelial cells, and the consequent cardiovascular damages with and without other risk factors. He discussed endothelium dependent relaxation, due to vasoactive substances produced by endothelium, which decreases with age with resultant cardiovascular changes and damage. He described a decreased vitality of 1% per year after age 30 and that the end of the 4^{th} decade endothelial dysfunction may precede clinical symptoms. Mentioned also described new therapies and behaviors (physical activity, smoking cessation and glucose intake restriction) which have been shown to improve endothelium function. He then described a study of 21 aviators with high blood pressure, mean age 46 years old, who were studied over the past 5 years. They found smoking in 24%, hyperlipidemia in 81% and increased BMI in 85%, and they were able to provide good control of HBP but not the other factors during this timeframe (in fact, 3 were disqualified from flying due to coronary artery disease). The author concluded that the real threat in military personnel may be endothelial dysfunction and not simply aging.

The next paper, #28 "The Modified Measurement of the Intima Media Thickness: A New Way of Dynamic Evaluation in Endothelial Dysfunction", was presented by LtCol P. Meyer. The authors, using B-mode imaging, measured the end systolic and the end diastolic intima-media thickness and the diameter of the common carotid arteries in 143 healthy volunteers. They found a linear correlation between end diastolic intima-media thickness and age beginning at age 40, averaging .1mm per decade. Wall motility was between 70-80% in young volunteers, and more than 30% even in 80 year olds, and thus interpreted a wall motility below 30% as endothelial dysfunction. Most volunteers with cardiovascular risk factors had a thickened intima-media layer and a pathologically reduced wall motility, sometimes in only one carotid artery but often in both. In patients followed one year, authors noted a reduction of the intima-media thickness within hours by successfully lowering blood pressure and an improvement of wall motility with new treatment or optimization of current treatment. In 50 patients with hypertensive crisis, within 30 minutes after successful therapy, they were able to reduce a thickened intima-media (mean of .11mm) and increase wall motility from below 30% to normal. In a study of 72 patients measured at rest and after exercise maximal testing, they found a significant thinner intima-media layer at rest compared to after exercise during high heart rate. They concluded, "Pignoli's assumption that a thickened intima-media complex reveals preatherosclerosis (with 0% wall motility) cannot be upheld any longer". By determining intima-media measurements at certain times in the cardiac cycle, besides age, the intima-media thickness is also influenced by high blood pressure and heart rate. Authors also conclude that their measurement methodology can differentiate real preatherosclerosis from increased vasotone, can evaluate the effect of single risk factors and therapies, and may be able to better "examine the long-term effects of adverse mission environments such as hypobaric or hyperbaric conditions".

Paper #29 was cancelled, so LtCol N. Ribiero presented paper #30 on "Portugese Air Force Study on Cardiovascular Risk Factors and Visual Acuity changes in Aging Crewmembers". He described data on 128 pilots examined at 5, 10, 15, 20 and 25 years of service, 64 male pilots age 16-28 years old and 62 pilots ages 40-58 years old. Data obtained included total numbers of pilots in categories of smoking, alcohol consumption, weight, visual acuity, BP, cholesterol and other pathology. Conclusions were that 54.6% smoked, 53.1% drank alcohol, 9 had significant (19%) weight gain, 4 had HBP, most had a diet conducive to increased cholesterol, and half of those with elevated cholesterol were in the age range 35-47. There was no significant difference in visual acuity with age.

As paper #31 was unexpectedly cancelled, Col. D. Ivan presented paper #32 "Ocular Problems of the Aging Aviator. The importance of ocular problems in older aviators was highlighted by the fact that 20% of USAF aviators and 62% of US civilian airline pilots were over 40 years old. Medical records of all USAF air crews over 45 years old referred to the Consultation service were reviewed over a 10 year period and outcomes were compared to those in 1959. Among 149 new cases reviewed, average age of 50 years old, there were 154 ocular diagnoses excluding presbyopia. All had presbyopia requiring correction by age 50 and all could be corrected. Diagnoses among the 149 included glaucoma in 27% (over 90% can be kept flying today with therapy); cataracts in 22% (all would have been grounded in 1967; now 94% returned to flying duties); ocular motility stereopsis problems (microstrabismus) in 12% (90% returned to flying status); retinal detachment (most had prior surgery) in 6% (all would have been grounded in 1959; now 89% returned to flying); keratonus (excessive myopia) in 5% (grounded if not corrected in 1959; now 100% returned to flying); and central serous retinopathy in 5% (no significant change since 1959; most heal without Rx and 89% returned to flying). The remaining 22% had miscellaneous diagnoses. Summarizing, excluding presbyopia, 78% had diagnoses that in 1959 were grounding conditions. Currently, however, among 30 aircrew members found not physically qualified to fly, only 12 (40%) were due to ophthalmologic diagnoses, and of these, 92% returned to flying duties. Conclusion was that, although aging causes an increase in presbyopia, glaucoma and cataracts (other conditions being similar in younger personnel), medical science and technological advancements made these ophthalmologic conditions amenable to successful treatment or correction so that they no longer should be a cause of a shortened flying career.

Col D. Ivan continued and presented paper #33 "Intraocular Lenses in Military Aircrew". Among the most dramatic advances in medical sciences during the past 75 years has been in microsurgical procedures. In 1967, the first aphakic USAF crewmember was returned to flight duty following cataract extraction optically corrected with a hard contact lens. Until the mid-1970s, the primary means for optical correction following cataract surgery was soft contact lenses, which ameliorated the G displacement problem. In 1979, the first USAF aviator was returned to flight status following insertion of an anterior chamber intraocular lens (the IOL procedure was first successfully accomplished in 1949 by a British Ophthalmologist using fighter aircraft canopy material). In 1979, a special USAF Intraocular Lens (IOL) Study Group was established to evaluate and manage these IOL treated aircrew for the duration of their careers. To date, 65 aircrew members, mean age of 44 at time of surgery, have had cataract extractions (15 in both eyes) with insertion of IOLs in a total of 80 eyes (95% into posterior chamber). Longest follow up period was 15 years. IOL surgery was successful, 97% had at least 20/20 vision post op (77% 20/15 vision). This Study Group recommended waiver in 90% to return to flight status, 3 were grounded for ocular reasons 3 for non-ocular reasons. Post-operative continued recommendation is for use of UV block eyewear to compensate for the removal and absence of the "natural" UV blocking lens.

Paper #34 "Visual Performance on the Small Letter Contrast Test (SLCT): Effects of Aging, Low Luminescence and Refractive Error", was presented by Maj. C. Van De Pol. Using standard and low luminance SLCT, where "20/25" letters decrease in contrast with each successive row, the authors compared visual performance in two groups, aviators and myopic non-military. Aviators performed better, mostly 20/20 or better, the mean difference being one line between groups. High contrast visual acuity remained fairly stable over the age groups, but decreased with increasing refractive error (thus lower scores with non-aviators). Standard and Low luminance SLCT visual performance decreased with increasing age, the greater effect (2 and ½ times) with low luminance. The authors concluded that visual performance was more important than chronological age and that key factors for aging aviators were ambient light and refractive error.

The last paper #35 "Modern Cockpits: Keeping in the Loop Year After Year", was presented by C. Roumes, who discussed the impact of age on perceptual performance (thresholds, discrimination) and cognition (memory, problem solving, psychomotor coordination and learning). With increasing age and experience, practice can improve behavior and procedures can be adjusted to overcome perceptual and cognitive impairment, but there are still residual problems in perceptual loss and as a result of technological gap (glass cockpit; fly-by-wire, etc.). Although everyone experiences some perceptual impairment, the perceptual margins are confounded among the older military operations crews by glare effect, decreased visual acuity along with decreased "cockpit" symbol size, etc. Solutions may involve compensating for decreased threshold values among older crews through technology at the design level of modern cockpits, such as by "over coding" signals, etc.

Concluding remarks were provided by CAPT Hibbs, who summarized the various types of data on aging crewmembers that were presented at the Symposium. In Session I, "Operational Aspects of Aging Crew Members", papers were presented on the effects of Gs, jet lag, spinal disease, ECG findings during centrifuge training, hypoxia tolerance and pulmonary function (in older divers). In Session II, "Aging Crewmembers: Psychological and Cognitive Performance Implications", papers were presented on sleep, working memory, risk taking, cognitive and sensory limitations, personality and behavior and neuropsychiatric referrals. In Session III, "Psychological and Sensory Aspects of Aging", data were presented on anthrax immunization, growth hormone, endocrine response to training, autonomic cardiovascular control, biochemical-metabolic indices, endothelial dysfunction, intima media thickness, cardiovascular risk factors, ocular problems and intra-ocular lenses, small letter contrast test and modern cockpits.

6. CONCLUSIONS

The Symposium was very successful in that much of the available data on the effect of aging on crewmembers was presented, referenced or discussed. A few studies included small samples but at least indicated trends supportive of larger studies. In combination, the papers represent a wealth of information, particularly suitable as reference in future studies, and this information is all the more important given the trends in many countries toward smaller, older military forces in the future. The increasing presence of women as crewmembers, and the paucity of data on women crewmembers in general (including aging women), highlight the necessity of acquiring this data whenever possible in future studies of crewmembers. One can conclude from the data presented that: (a) During these times of prevention, health promotion and healthy lifestyles, physiologic age of individuals seems to be more important than chronological age of groups; (b) Knowledge, behavior and experience seem to adequately compensate for aging crewmembers in military environments; and, (c) The above, combined with new medical and surgical therapies and technological advances (in equipment designs, etc.), appear to justify seriously re-looking at current age policies for military crewmembers (particularly if, and when, a country's military manpower and budget projections deem it appropriate).

Discours d'ouverture

César ALONSO RODRÍGUEZ
Président du Comité pour le Programme Technique de la Conférence

Monsieur le Préfet, Monsieur le Député, Amiral, Messieurs les Officiers Généraux, Mesdames et Messieurs,

C'est un honneur pour moi de présider, avec le Médecin en Chef Lagarde, le dernier Symposium de la Commission de Médecine et des Facteurs Humains du 20ème siècle.

A la différence des symposia des autres Commissions du RTO et même de plusieurs Symposia de notre propre Commission, celui que nous débutons aujourd'hui sur les Conséquences Opérationnelles du Vieillissement des Equipages est dédié à l'homme qui constitue la partie la plus importante du binomium homme-machine, concept utilisé à l'origine dans le cadre de l'aviation de combat, mais qui peut être applicable à tous les systèmes d'armes. C'est l'homme qui conçoit, construit et contrôle les systèmes de défense et d'attaque utilisés au cours des opérations militaires.

En 1980, avec l'apparition de la nouvelle génération d'avions de haute performance, capables de générer et de maintenir de hautes accélérations dépassant la capacité maximale de tolérance humaine, le Dr Hickman a défini l'homme comme le "maillon faible" de la chaîne homme-machine. A mon avis ce concept peut être applicable à beaucoup d'autres systèmes utilisés en opérations militaires. Au cours des prises de risques inhérentes au pilotage des avions de combat, au transport en hélicoptères, à la conduite de véhicules blindés ou au passage à pied sur un champ miné, et ce plus particulièrement en temps de guerre, l'homme est toujours le point faible du complexe homme-machine malgré l'utilisation actuelle de moyens de protection sophistiqués.
De la même manière que les aéronefs et les matériaux utilisés, les équipages responsables de leur fonctionnement souffrent aussi des effets du vieillissement. Eh bien, l'un des objectifs de cette conférence est de revoir la connaissance actuelle de l'évolution de la performance de différents équipages militaires en relation avec la réalisation de missions spécifiques pendant les années écoulées depuis leur admission vers l'âge de 20 ans jusqu'à la fin de leur carrière (60 ans ou plus).

Alors qu'il reste moins de trois mois avant de changer de siècle et de millénaire, je me permets de faire deux réflexions sur les changements subis au cours du siècle que nous sommes en train d'achever ; ces deux réflexions sont en relation avec le concept du système homme-machine, dont la bonne intégration se traduit par une augmentation de la capacité opérationnelle.

Ma première réflexion se situe par rapport à l'homme: nous savons que l'homme existe depuis un million d'années, alors que les premières civilisations datent seulement de 6000 ans. Il n'y a pas de données fiables sur l'évolution de l'espérance de vie pendant l'histoire, mais on estime que pendant la période de domination romaine, la moyenne de vie était de 30 ans. Ce chiffre n'a guère changé pendant les 1900 années suivantes puisque au début du siècle actuel, l'espérance de vie était de 40 ans (47 aux Etats-Unis). Au cours de ce siècle, dont la première partie a été marquée par la révolution de la physique et la fin par une révolution incroyable des connaissances en biologie, l'espérance de vie a presque doublé en passant de 40 ans à près de 80 ans dans les pays industrialisés, parmi lesquels se trouvent la plupart des pays de l'OTAN; et on peut espérer que les changements, dans un avenir proche, seront encore plus profonds.

Ma seconde réflexion porte sur les changements subis en technologie au cours de ce siècle. J'ai eu la curiosité de faire des recherches sur ce que l'on avait découvert ou sur ce que l'on pouvait retenir de marquant en 1899. J'ai consulté de nombreuses sources, y compris bien sûr Internet, mais je n'ai rien trouvé de remarquable.
Mais soudain, voici un mois, dans une revue, j'ai lu une phrase écrite en 1899 qui s'explique d'elle-même, ne nécessite aucune explication supplémentaire, et qui peut nous ouvrir les yeux sur la manière dont les choses ont changé au cours du 20ème siècle: "Une machine plus lourde que l'air ne sera jamais capable de voler" (William Thomson, Lord Kelvin, 1899).

Les considérations sur la répercussion de l'augmentation de l'espérance de vie sur le vieillissement des équipages, ainsi que les avances en technologie, seront développées au cours des présentations de ce Symposium.

Je tiens ici à remercier tous les membres du comité scientifique, et je veux nommer:

le Médecin en Chef Didier Lagarde (France) mon co-président
le Dr Hibbs (USA) qui rédigera le rapport d'évaluation technique de ce symposium
le Dr Tielemans (Pays-Bas)
le Dr Salisbury (Canada)
et le Dr Rios-Tejada (Espagne)

En leur nom et le mien, je remercie également:

- les autorités françaises pour nous avoir accueillis et donné toutes les facilités pour développer les activités de notre Commission dans cette attirante région de France près de la Côte d'Azur;

- le comité organisateur local constitué du Prof. Menu et de son équipe, qui ont fourni beaucoup de temps et de travail dans l'organisation des activités scientifiques de la Commission et dans l'excellent programme social dans lequel le Médecin en Chef Lagarde a joué un rôle important;

- les auteurs, pour leurs contributions dans un domaine non encore bien défini et dans lequel beaucoup est encore à faire dans le futur;

- notre efficace Administrateur de la Commission RTA/HFM à Paris, le Dr Cornelis Wientjes;

- Mrs Dany Grasset-Michel pour son excellent travail réalisé au cours de la phase préparatoire et pendant le déroulement de la conférence. Elle m'a beaucoup aidé en prenant contact avec des auteurs internationaux dans le domaine du vieillissement, en obtenant des données de différentes nations sur l'âge d'admission et de retraite des équipages et surtout en résolvant avec efficacité un grand nombre de problèmes.

- aux Interprètes et aux techniciens pour leur excellent et difficile travail dans l'anonymat;

- et enfin à vous membres de l'audience qui, par votre présence et votre participation active en posant des questions et en faisant des commentaires, contribuerez au succès de cette conférence.

Welcoming Address

César ALONSO RODRÍGUEZ
Programme Committee Chairman of the Symposium

Ladies and gentlemen,

It's an honour for me to chair with Colonel Didier Lagarde (FR), the last symposium of the Human Factors and Medicine Panel of the twentieth century.

Unlike the activities of the other RTO panels and even of our own Panel, the symposium that we are about to start on "The operational issues of ageing crew members" is devoted to the human being, which constitutes the most important part of the man- machine binomium. This concept was originally introduced in relation to the combat aviation, but could be extended and applied to other weapon systems. In fact, they are men who make the designs, manufacturing and control of the defence and attack systems used during military operations.

In relation with the introduction in the 1980s of a new generation of high performance fighter aircraft, with the capability of generating high onset rate and sustained accelerations, overexceeding the maximum human tolerance to G forces, Dr Hickman defined man as the weak link of the man-machine chain. From my point of view this concept can be applied to many other aspects of the military missions. While facing the risks inherent to flying fighter aircrafts or helicopters, driving armoured vehicles or walking on a mined terrain, and specially during war time, man become the weak point of the man- machine complex, regardless of the utilisation of modern and sophisticated protection devices. Additionally, in the same way as for aircrafts, vehicles and other materials utilised, the crewmembers responsible for their functioning also suffer the effects of ageing. One of the aims of this conference is to address the present knowledge about the evolution of the crew member performance in relation with conducting specific missions during the years elapsed from their admission at an age of about twenty years old until the end of their careers (sixty years old or more).

Only three months separate us from the turning of this century and millennium; I permit myself to make two considerations about the changes experienced during the century that we are about to end, in relation to the "man-machine system", whose good integration turns into an increase of the operational capacity.

My first consideration is about men. Although man is on earth since one million years, the first civilisations only have six thousand years. There are no reliable data about the evolution of the man life expectancy throughout history, but it has been estimated that during the roman period the life average was thirty years. This number has almost not changed over the following 1900 years, because at the beginning of the present century the average life expectancy was 40 years (47 in the United States). Throughout this century, in which the first part has been relevant by the revolution in physics and during the final part by an incredible revolution in the field of biology, the human life expectancy has almost doubled, increasing from 40 years up to 80 years of age in industrialised countries, situation in which most of the NATO nations are considered. Hopefully these changes will be even deeper in the near future.

My second consideration is about the technological changes experienced during this century. I had the curiosity of searching about the relevant findings and research conducted in 1899. After consulting many sources, including Internet I found no relevant events. But suddenly, a month ago in a journal, I read a sentence written in 1899 which by itself explains the way in which things have changed throughout the XXieth century. "A machine heavier than air will never be able to fly" (William Thomson, Lord Kelvin 1899).

Considerations about the effects of the increase in life expectancy over the crew members ageing, as well as the technological advances will be developed during the presentations of this Symposium.

I want express my recognition to the members of the scientific committee:

Colonel Didier Lagarde (FR), my co-chairman
Captain (US Navy) R. Hibbs responsible for writing the Technical Evaluation Report of this symposium
Dr W. Tielemans (NE)
Dr D. Salisbury (CA)
Dr F Rios-Tejada (SP)

In their names, I would also like to thank:

The French authorities for welcoming us and for providing us with the facilities to develop all the activities of our Panel in this beautiful region of France, near the Côte d´Azur.

The local organising committee constituted by Prof. Menu and his team, who have devoted a lot of time and efforts to set the scientific activities of our Panel and an excellent social programme. Dr Lagarde who played an important and active role.

The authors for their contribution in a field not well defined in which there are a lot of things to do in the near future.

To our efficient Panel Executive RTA/HFM in Paris, Dr Cornelis Wientjes.

To the outstanding work conducted by Mrs Dany Grasset-Michel throughout the entire conference preparation process. She provided me with great assistance by establishing contact with international authors in the field of ageing, collecting age policies data from different nations and readily solving a countless number of problems.

To the interpreters and technicians for their excellent and difficult task.

And finally to the members of the audience, who have contributed with their presence and active participation to the success of the conference

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Aging Crew Members.
Physiological and Operational Considerations

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Aging is a complex process which implies changes in the human physiological functions and body composition, which may be, in part, the inevitable result of a genetically programmed process that determines the lifespan duration. Aging is considered as an irreversible process which evolves after certain age with progressive loss of physical and mental capacities of individuals.

Most of the current literature identifies aging with senescence and the research in this field is mainly conducted in people over 70 years of age, eluding to consider the physiological changes occurred during the previous decades, when there is evidence that many aspects of the human performance start to decline at much earlier age in mid life, with possible repercusion in some prfessional tasks .

One of the major concerns of the military medicine is to maintain the crew members fully operational during their careers, in spite of the increasing age. In this regard, it is important to study the evolution of the different military crew members performance, conducting specific missions througout the years elapsed from their admission with usually twenty years of age to the end of their careers in some instances in the sixties. The little attention paid to this active duty period of life which in many instances accounts for more than fifty percent of the duration of total lifespan, is due to the assumption that only minor changes in performance are taking place, and consequently they do not affect the efficiency in the accomplisment of the missions. On the other hand , it is generally accepted that during this period, expertise overcomes the slight physiological changes occurring with aging..

Mechanisms of aging

Aging is a complex process, conditioned by a genetic predisposition and influenced by environmental factors and the risk of appearance of chronic and acute diseases. These variables interact one with another, determinining the manner in which we age.

Aging is associated with a variety of events including the *oxidative stress* due to the non-enzymatic free radical-mediated oxidation of biological molecules, membranes and tissues and a sharp reduction in antioxidant defences (1,2). It has been reported an increased sensitivity to the oxidative stress as an age-related change that occur in neuronal function. There are evidences that the abilities to mitigate the oxidative stress effects and to repair its damage show a decline as a function of age (3). It has been described both in men and animals that the endogenous levels of antioxidants in tissues negatively correlate with the maximum lifespan, and that the most longevous men and animals studied showed the minimum level of antioxidants. A possible explanation is that the longevous animals produce oxygen radicals at a low rate, according to analysis conducted at the mitochondria level, where more than nintyfive percent of the oxygen is consumed in the cells. In this sense, most authors agree that the longer the lifespan, the lower the rate of mitochondrial oxygen radical production in combination with a higher rate of DNA repair. Simultaneous consideration of these two facts can explain part of the quantitative differences in longevity between families (4).

The non-enzymatic glycation, a reaction in which molecules of glucose are covalently attached to free amino groups and ultimately form Advanced Glycosilated End Products (AGE) which modify the structural and functional properties of proteins, lipid components and nucleic acids, eliciting a wide range of cell mediated responses (5,6) , have been reported to occur during the normal aging process.

The normal aging process is closely related with the changes that occurs in the human endocrine system, such as the decline or arrest of the reproductive functions in men and women, respectively, the decreased of the adrenal function and of the growth hormone secretion, the development of insulin resistance, as well as the changes in calcium, water and electrolyte metabolism. These age-associated changes in the endocrine function should not be considered simply the result of aging because they might play a direct causative role in the aging process. In this regard it has been reported that "general well being" is accompanied by a more youthful hormone profile, for example of dehydroepiandrosterone levels, raising the question whether hormonal replacement to achieve the levels of hormones observed in youth may retard the development of signs and symptoms of aging (7).

Paper presented at the RTO HFM Symposium on "Operational Issues of Aging Crewmembers", held in Toulon, France, 11-14 October 1999, and published in RTO MP-33.

No other medical speciality is replete with examples of normal age-related changes and age-prevalent diseases as the endocrinology.

Major hormonal axis are affected with aging, however these alterations are confounded by multiple factors interacting with the endocrine function, including co-existing illnesses, age-related changes in physical activity, anthropometric measures, diet and sleep-wake cycles. Additionally, the measurement of plasma or urine concentrations may not provide an accurate index of changes in circadian variation in secretion of hormones that occur with age. Measurement of plasma hormone concentrations should be interpreted in the context of age-related alterations in binding plasma proteins, rates of secretion and clearance of the hormone from plasma and with changes in target tissue sensitivity at receptor and postreceptor level. With age basal levels of many hormones remain normal but they are shown to be reduced under stimulations such as stress, translating a lack of the reserve capacity of the system (8).

Aging in humans evolves with progressive changes in body composition which are evident in the second half of the human life cycle. The most documented modification is the lean body mass which shrinks with advancing age and there is an atrophy of approximately 30% from age thirty to age seventyfive in the size of muscles, the liver, kidneys, brain and pancreas. The body weight tends to remain stable because of reciprocal expansion of the adipose tissue. The functional capacity of most organs decline (9) and progressive reductions occur either in basal performance and in response to specific stimuli by the muscles, kidneys, heart, lungs, gastrointestinal tract, liver and brain. Peak bone mass is reached between the ages 30 and 40 years and then followed by a gradual loss of bone mass. These functional impairments restrict the capacity of the aging person to undertake activity, withstand trauma, resist infections, process food and excrete medications.

The age-related changes in body composition are undesirable due to the following facts: 1) Aerobic work capacity is directly proportional to the lean body mass. 2) The atrophy of the lean body mass organs is associated with diminished functional capacities in muscle strength, glomerular filtration rate and renal blood flow. 3) Increased adiposity predisposes to unfavorable changes in blood pressure, glucose clearance and plasma lipoproteins

Aging evolves with a decline in the immunological functions and consequently is responsible for an increment in the susceptibility to some infectious diseases that occur more severely and to the development of cancer and autoinmune diseases. In this sense one of the most well known facts associated with aging is the thymus involution with a significant mass reduction after puberty. A diminution of relative proportions of T cells CD4 and CD8, especially the first type , with a decrease of CD4/CD8 ratio. The T linfocytes proliferation in response to mitogens is diminished. The capacity of rejection to allografts and tumoral cells is impaired. The capacity of production of certain cytokines (interferon, IL-2) by linfocytes decreases with age and it has been observed a descent of the antibody production in response against specific antigens (10).

Aging evolves with sleep management disturbances and the nightime sleep becomes shorter, lighter and more disturbed with a reduction in the amplitude of the sleep/wake cycle, which may forme part of the general attenuation of the circadian rythms with increasing age. There is also an impairment of the sensory perception including a progressive visual and hearing loss as well as deterioration of the smell and taste perceptions occurring overtime.

Many of these physiological changes start to be evident when the military crew members are still on active duty and have important operational consequences. The loss of muscle mass reduces strength, mobility and flexibility, abilities which are required in most of the military missions. Similar operational repercusions can be produced by the decline in sensory perception , thermal stress tolerance and resistance to fatigue.

Life Expectancy .

Aging is a continuous process which starts at birth and proceeds irreversibly along the individual lifespan until his/her death. The life expectancy is one of the major parameters to be considered when assessing the human aging, especially the life expectancy at birth, which is the expected mean life duration of a population since birth. Unlike the maximum life potential which varies among the different species and is similar within the same species and which have changed very little during the evolution, the life expectancy depends very much on the environmental influences and has increased considerably over the last century. By means of improving the population health status it has been accomplished to increase the life expectancy at birth globally by 17 years in only 40 years, from 48 in 1955 to 65 in 1995 and is projected to reach a level of 73 years by 2025 (11).

In the world in 1955 only 32% of the population had a life expectancy at birth above 60 years, while in 1995 this percentage have increased up to 86%, and the prospect for the year 2.025 is 96% (11). This increment in life expectancy, greater than the attainted over the last centuries has been due to the

reduction of the infant and children mortality rates, to the improvement in the life standards and the advances in preventive medicine and medical care, which have eliminated the threat to life imposed by many illnesses. Although, it could be expected that the reported lengthening of life expectancy would be accompanied with increasing chances of morbidity and disability, it has been reported that life expectancy without severe disability at age 65 progresses in parallel with the increase in total life expectancy in most of the developed countries (11).

The life expectancy at birth in NATO nations has also increased considerably over the last fifty years and actually, the NATO countries, most of them developed market economies, are listed among the first in the world regarding life expectancy. In this regard in the 1998 WHO report, the majority of NATO countries, with few exceptions, have a life expectancy at birth of more than 75 years and it is expected to be increased by an average of three or more years in 2.025 (table 1) (12). It is important to mention that adults aged 20- 64 are the chief beneficaries of improvements in life expectancy during the last fifty years.

Another parameter related to aging is the survival rates or chances of surviving 65 or 80 years which also have improved significantly during the period 1955-1995 and it is expected to improve further up to the year 2.025 (11). For every 100 newborns in 1.995, 70 of them are expected to live at least 65 years, and for every 100 persons aged 20 in 1.995 about 70 are forecast to survive 50 more years, to age 70.

The general trend in the percentage of deaths occurring in the various age groups is going downward, except in the older group. In the developed market economies in which can be included the NATO nations, there has been an important reduction in the number of deaths occurring among the population aged from 20 to 64 years, period in which the active duty crew members are included, from 35 % in 1.955 down to 21 %, expecting a further reduction to 14% by the year 2.025 (11). The number of deaths occurred in subjects under age 50 in the different NATO nations are expressed as percentage of total in table 2 (12).

In relation to the disease trends, the WHO estimates that the deaths worldwide in 1.997 are due : One third to infectious diseases including tuberculosis, HIV, malaria, hepatitis; 29 % to circulatory diseases and 12 % due to cancer. In the developed world is different and the cardiovascular diseases, although have been declining from 51 % to 46 % of the total number of deaths during the period 1985-1997, are still the leading cause of death, the deaths due to cancer form a constant proportion of 21 % and the infectious and parasitic diseases have decreased to 1 % of total deaths.

NATO crew members age policies

A survey has been conducted earlier this year among the NATO nations, to know the age limits of admission and retirement for the personnel of the Armed Forces including the Army, Air Force and Navy Services (table 3) as well for the crew members having specific missions. The survey considered fighter pilots, helicopter pilots, submarine crews , divers and armour vehicle as specific crew members (table 4). Ukraine and the Republic of Macedonia kindly volonteered to present their data.

The majority of the national policies are based on the chronological age , including the admission and retirement . In relation to the age of admission there are similarities between nations, establishing 18 years of age in most cases, with slight variations , ranging from 16 to 19 years. In relation to the age of retirement, the differences between nations are bigger, from a minimum of 49.5 years up to a maximum of 65 years of age.

In some nations the age of retirement varies between officers and NCO, and in other it depends on the military rank , in general the retirement is later for senior officers and generals than for the lower rank staff. In a few nations the age of retirement is not set at a preestablished age, but it is conditioned by the number of years on active service. This is the case of the three US Services, in which the retirement is currently established after 30 years of service. In some other nations the date of retirement is also conditioned by the number of years of active service, but existing an age limit that should not be exceeded. The possibility of an extension of the military career duration it is affordable under request in some nations, generally after certification that the military person is physically and mentally fit.

In regard to the military crew members conducting specialized tasks (fighter pilots, helicopter pilots, paratroops, submarine or armour vehicle crews) the majority of the nations do not have specific age policies different from the existing in general Armed Forces (CA, DK, NO, PO, PL, TK, UK, US) although these jobs are mostly occupied by young crew members , usually in the twenties and early thirties. The time of permanence of these crews is set in function of the military command operational needs and the results of the periodical psychophysical exams.

In other nations, in some instances, the time of permanence of some specific crews doing the missions, is limited until a fixed preestablished age, although they can continue afterwards on active service commited to other assignments until

reaching the current age of retirement. This is the case of the German Navy and the Spanish Navy in which the submarine officers have a limited retirement age of 38 and 40 years , respectively

Reasons in favour and against setting a determined age retirements

Old age is an abstract concept and consequently is no longer accepted unquestioningly as beginning at a fixed chronological age, such as the age of retirement from work .

Many people approaching their retirement feel that they have still plenty of capacity and experience to continue doing the job that they have been doing during the past decades and especially it happens in some specialiced activities such pilots or navy officers. For many military staff passing from full time work to full time retirement at a pre-established age the day after his birthday, when they still feel reasonably fit, considering that they could continue running efficiently their activity during a longer period of time, constitutes an abrupt step and in many instances a trauma (13). This is the case of many military officers and NCO that in some nations have to retire involuntarely at 55 years and some instances before that age. Unlike this position they are who feel that military missions should be run by young fit and trained crews and consequently the ages of retirement should be anticipated in future revisions.

In favour of establishing standards with fixed retirement ages, before 60 years of age, there are clinical evidences, some of them are next commented.

Age is an important risk factor of cardiovascular disease (CVD)(14,15). In this regard CVD, including acute myocardial infarction, ischemic heart disease and hypertension, has been reported to be rare in pilots under 35 years of age, but its incidence increases more than threefold at age 36, rising dramatically after the 48 years of age (14) (23) . These findings may have some relation with the observation that mean cholesterol values tend to increase with age, as it has been observed in pilots, approximately 1-2 mg/dl per year, increasing the cardiovascular risk (16). The same can be said regarding the risk of developing type 2 diabetes mellitus which significantly increases with age in developed countries (17).

In a study conducted in airline pilots with ages between 20 and 69 years, it was observed that the rates of incapacitation and death increased slowly and progressively with the age up to 59 years. In the group of pilots with 60 years or more the incapacitating pathology suffered a sudden an abrupt increase (18). It was considered the consequence of the chronic degenerative slow evoluting pathology, closely linked to to age decay.

An analysis of disability prevalence in relation to aging, due to chronic rheumatic diseases including osteoarthritis, rheumatoid arthritis, low back pain, osteoporosis and other joint and soft tissues diseases, conducted in several nations showed that the frequency of disability increases roughly 3-5 times between the group aged 30-44 and the group aged 60-64 years. There is also a slight increase in the risk of injury with aging, and the rate of recovery after injury is slower in aged people (19).

The gradual elimination of other fatal diseases associated to the increase in life expectancy in NATO crew members, make them at higher risk of having cancer during their lifes. The risk of cancer increases steeply with age. The 1998 WHO Report estimates that the average age at death from six of the most common forms of cancer ranges from 61 to 69 years in a sample of six countries (19).

Another important reason for setting the retirement age not later than 60 years is the observation that the risk of developing dementia rises steeply in people with 60 years and more (18).

In a study performed in two groups of healthy subjects with a normal intelligence quotient, one aged 30-39 years and the other 60-69 years, conducting a Multiple Task Performance Battery to produce synthetic work situations, including: monitoring of warning lights, monitoring of meters, mental arithmetics, pattern identification and tracking tasks. The results demonstrated that older subjects performed more poorly than the group of younger subjects on all the tests of performance (20). There is extensive literature reporting progressive deterioration of sensory, perceptual, decision and psychomotor processes over time, starting in early mid life (21,22,23,24), including abilities to perform complex tasks rapidly, to adapt to new and quickly changing conditions, to process incoming information, to make complex decisions, to resist fatigue and to act efficiently in stressful environments.

On the other hand there are authors who consider there are enough *reasons in favour of postponing the current retirement age policies*. The consideration that aging is not an homogeneous process, that there is not one single way of aging but different individual types, involving several biological (unmodifiable), psychological, social and subjective (modifiable) factors, supports this point of view. There is a lack of scientific agreement about the ages at which mental and physical performance suffer deterioration and the extent of it.

The consideration that the crew members experience, a variable highly correlated with age, can offset the previously reported increased risk of sudden incapacitation, and the description that crew inexperience may result in an increased rate of errors (25). Age has been considered by some

authors to be roughly equivalent to experience level in pilots and other crew members, due to assignment and career progression in many Armed Forces (26).

The evidence that some of the age-related physiological changes are the result of the lack of physical activity and can be prevented introducing lifestyle changes (27), invite to reconsider and in most instances postponing the retirement age policies. Now it is accepted that a significant component of what was once believed to be age – related muscle deterioration is the result of disuse atrophy. Review of track and field records of well conditioned athletes, indicate that only a gradual decline in peak performance take place through the first six decades of life. Deterioration in peak physical performance is more rapid in events that require speed and power that in those that stress endurance (27). Based on this fact, some authors consider that chronological age of adults, in the absence of disease should not be a limiting factor until advanced upper age levels are reached (28). A study conducted in airline pilots, concluded that 64 % of them with 60 years of age were perfectly capable of continuing their activity both from the physical and psychological point of view (18).

For some authors , there are other major risk factors such as hypercholesterolemia, hypertension, and the family history of cardiovascular disease, than the age itself in prediction of sudden incapacitation (29). Older crew members are at lower risk during their missions than their younger companions with cardiovascular risk factors (29, 30).

Accident rates decrease progressively as professional pilots grow older (31), and also as the number of hours flown by the pilots increase (32).

With the increasing life expectancy and relative aging of our population, we must keep that aging population productive (25), and premature retirement from the professional activity leads in to reactive depressions, in some instances preretirement and to the reduction in preventive health care (18).

Aging crew members operational aspects. Specificity of the missions.

Assuming that the aging process evolves with gradual loss of physical performance, in some aspects starting in the twenties, it could be deducted that the younger the crew members, the better their mission accomplisment, especially when the missions are physically demanding.

There are very few publications available comparing the performance of different age-group crew members in relation to specific military operations such as fighter pilots, submarine crews, divers, infantry troops, etc but there are some data extracted from the field of the sport medicine which can be extrapolated to the military activities, which in many instances demand a great deal of physical and mental effort.

Data from archival sources on olympic track and field and other sports showing that the age at which peak performance is achieved has remained remarkably consistent over the last ninty years, while absolute levels of performance have increased dramatically. Data show that physical tasks requiring strength, speed and explosive power reach their peak in the early twenties, while tasks requiring endurance, acquired skill and knowledge peak in the early thirties, the roles of biology and learning should be subject of discussion (33).

As previously mentioned, aging evolves with changes in body composition, with a linear increase in weight and fat tissue and a slight reduction of the fat-free weight (FFW). In a study conducted in 410 male pilots with ages between 20 and 68 years, it was reported that the body weight increased by 3 % from age 30 to 49 years due to the increment in fat. The aerobic work capacity (VO2max) was falling at a rate of 0.25 ml/min/ Kg per year, contributing to the fact that the maximal amount of work capacity diminishes linearly with age (34). The reduction in VO2max/FFW suggests a loss of efficiency in working muscle with age. In this regard it has been demonstrated that about 50 % of the decline of the VO2max between ages 30 and 70 is the result of loss in muscle mass (35), although part of the VO2max decline could be due to oxygen transport reduction. with aging, mostly due to increasing inhomogeneity of muscle blood flow distribution or reduction in muscle oxygen diffusing capacity (34).

One tangible measure of proficiency in military missions is the crew members involvement in operational errors as a function related to age. In regard to pilot implications in aircraft mishaps in function of age it has been reported that among fighter pilots the aircraft accident rate was higher for pilots under 26 years, while not observing significant differences between the other age groups (21). Within the community of attack pilots, the pilot factor mishap rate remained constant in all age groups, except for the older of 34- 47 years, whose accident rate was significantly lower. Among the helicopter pilots no significant differences were found between the different age groups, although the mishap rate tended to increase with age (21). In these studies , there are factors that are not considered such the history of transition to different aircraft types. Skill is gained through experience compensating for the physiological decline in individual cognitive or psychomotor capacity starting in the mid thirties (21).

Flying high performance fighter aircraft has been considered one of the most demanding military tasks during the last two decades. The fighter pilots have to expose themselves to a rapid onset rate,

long duration and high intensity repetitive accelerations, to rapidly changing cockpit pressures, to wear complex life support systems, and to control the new generations of weapon systems and flight controls sometimes in hostile environments. During the high G missions, pilots have to conduct the anti-strainning maneuvers which require muscle contractions especially involving the muscles of the chest, neck, shoulders,upper limbs and abdomen, to prevent the G induced loss of consciousness (G-LOC) . Assuming that muscle mass suffers a progressive reduction with age, starting at early-mid thirties, it could be assumed that fighter pilots should be under that age. Addressing this problem, a large study conducted in 1.434 fighter pilots aged 22- 55 years during high G training found no significant differences regarding G tolerance or susceptibility to G-LOC on the basis of age. Paradoxically there was a weak correlation between the centrifuge gradual onset run G tolerance and the pilot age (36). According to these results, pilots can not be reliably separated into categories of G tolerance based on the chronological age.

Age may be an important issue to be considered in military operations implying shiftwork missions or those conducted during or after time zone crossing flights. The trend of the quality of the sleep to deteriorate with age (37) together with the increased reduction in nigthtime sleep hours proper of aging produces cumulative fatigue and increases sleepness during the day (38). These facts can have detrimental effects on safety margins in military operations making difficult the crew adaptation to mission demands (39). Reports to the NASA Aviation Safety Reporting System indicate that about 21 % of all reported incidents are fatigue-related, and these incidents tend to occur more frequently in the early hours of the morning (40). In this regard it has been reported that among crew members flying longhaul operations, those aged 50 to 60 years averaged 3.5 times more sleep loss per day than subjects aged 20 to 30 years, contributing to performance decrements and compromising the aviation safety, suggesting that experience alone does not counteract the effects of aging, in this aspect (39).

In relation with the space operations, it was postulated more than thirty years ago that chronologic age in the absence of disease is not a valid reason when selecting individuals for space flight. Dr Mohler proposed three requirements as pertinent to clear candidates to astronauts: 1) To rule out impairing conditions in regard to the mission requirements. The forecast changes should not likely to occur for at least two years following the duration of the space mission; 2) Ability to perform the mission requirements; 3) Motivation to undertake the mission (28). Some of the changes observed in the human body during space flight are similar to those observed in the process of aging, including the loss of muscle mass and strength, bone density loss, cardiovascular deconditioning and changes in balance and coordination, effects that presumably would be more intense in aged astronauts. With the space flight of astronaut John Glenn in 1998 when he was 77 year old, 36 years after he went first out to space to orbit the Earth, and his excellent performance, there is an objective evidence that Dr Mohler´s proposal, made 37 years ago, has been confirmed to be true.

Aging also has implications in diving operations. Aged people tend to become less fit and fatter and consequently at higher risk of decompression sickness because of increased bubble formation after dives. Aged divers are at higher risk of sudden incapacitation in the water in comparison with their younger counterparts. In them experience should provide the ability to realise their own limitations facing missions which imply risks.

Prevention

Aging is a continuous and irreversible process which can not be prevented but its effects can be softened by introducing lifestyle modifications. As life expectancy increases, record numbers of people are remaining active well into their later decades (27). The measures to be adopted by the crew members are common with those recommended to the general population, including exercise, nutrition and lifestyle habits.

Exercise. For aging, exercise is an important preventive activity. Regular physical activity elicits a number of favorable responses that contribute to healthy aging. Crew members participation in regular exercise programmes is an effective intervention devoted to prevent and reduce a number of functional declines associated with aging starting at intermediates ages.

Endurance training can help to maintain and improve several aspects of cardiovascular function, as measured by VO2max, cardiac output and arteriovenous oxygen difference, as well as enhance submaximal performance (41).

Strength training contributes to diminish the loss in muscle mass and in strength associated to normal aging, diminishing the risk of injuries. Additionally, it improves the bone health with reduction of the osteoporosis rate, improving postural stability and increasing flexibility and the crew member operational capability (41). In order to prevent the aging physiological muscle mass loss, regular vigorous exercise programmes have achieved in pilots an increase of the VO2max/ weight ratio of 17 % , while a control group of sedentary pilots of the same age had a 12 % of reduction (34). Two

months of training raised the aerobic capacity and the maximal stroke volume by 15 %, lowering the maximal heart rate during ergometer exercise. Regular exercise also provides psychological benefits related to preserve cognitive function, preventing from depression and improving the concept of personal control and self-efficacy with better functional capacity and quality of life.

In a questionnaire conducted in 1992 among the NATO nations, the percentage of aircrew members doing regular exercise was in some nations far from the expected one hundred percent. In only few nations the crew members participated in regular exercise programmes, and the majority had great dificulties to do it (table 5) (42). Although these data have probably improved in most nations over the years elapsed since the questionnaire was conducted, it is important to continue encouraging nations to provide facilities and the required available time to permit the crew members to participate in training and maintenance aerobic and strength exercise programmes in order to obtain the above mentioned benefits.

Diet also plays a important role in softening the effects of aging. The energy intake should be elaborated to fulfil the mission requirements and to reach or maintain a suitable weight according with the individual stature avoiding obesity, condition which limits mobility and agility and compromises operational capacity. Reducing the food intake of rodents to well below that of ad libitum fed animals increases the lifespan. This action known as the antiaging action of dietary restriction is related to alterations in the characteristics of carbohydrate metabolism and oxidative metabolism and not to the reduction of the body fat content, protecting against the damaging actions of acute stressors (43). The diet should containt the nutrients according to the current dietary guidelines, and the consumption of alcohol and caffeine should be regulated . The nations should provide proper catering facilities with adecuate menus elaborated by dietitians during both in peacetime and war operations.

Attempts to increase antioxidant protection through diets containing fruits and vegetables identified as being high in total antioxidant activity might prevent or reverse the deletereous oxidative stress effects on neuronal aging (3).

Preventive health strategies trying to motivate crew members to exchange bad health habits for good ones, will result in improvement of performance, retarding the speed of aging, becoming physiologically younger, and in the long run in an increase of the healthy life expectancy.

In a study conducted during 28 years in more than eight thousand men, trying to identify the risk factors that predict staying healthy in contrast to developing clinical illness and/ or physical and mental impairments it was found that the most consistent predictors of healthy aging were low blood pressure, low serum glucose, not smoking cigarretes and not being obese (44). Smoking cigarettes is still a strong habit in some NATO countries regardless the well known harmful effects, as it is reflected in Table 6. Incapacitation or sudden death from an acute myocardial infarction it is difficult to predict in crew members on the basis of an individual's past medical history. In a group of U.S. Navy pilots who suffered acute myocardial infarction, 83.9 % had no cardiovascular event prior to hospitalization (14).

The concept of Real Age it has been introduced to express the gains in life expectancy achieved from medical interventions. It is the measure of the physiologic improvement that results from an intervention affecting health, and tanslates the estimation of increased life expectancy into net present value. For instance, a 49 year old man who controls his blood pressure, quits smoking cigarretes and exercises may have a real age of 37 years (45). The periodic calculation of healthy life expectancies permits the evaluation of the impact of new health policies at a given moment as well as the assessment of trends under changing health conditions. The results obtained should be interpreted by experts (46).

It has been reported the existence of a correlation between higher education and higher life expectancy and lower morbidity leading to the conclusion that increasing the socioeconomic level and education of the military crew members can improve the health status and the operational efficiency and safety (47)

The age of the crew member participating in military operations can contribute to an increase rate of suffering fatal injuries, similarly to what has been reported in relation to aging workers experiencing an increasing risk of traumatic occupational fatalities (48). Deaths occurred among the crew members, currently aged 20- 60 can be considered as premature and they constiyute a huge loss of economic productivity. It deserves that the nations target this problem with prevention efforts devoted to avoid acidents in aging crew members. Preventive measures directed to reduce the risk of injuries and the risk of death by proper training, including the use of the protective life support and other operational equipments, has been proven effective increasing the survival rate in case of accidents (49). The Armed Foces Medical Services should undergo actions in order to address the above mentioned issues, making the necessary decisions and investments.

There are other specific health risks including environmental agents to which crew members are exposed. For instance aircrew members are exposed to cosmic radiations and magnetic fields generated by the aircraft's electric systems. Other possible factors are noise, vibrations, hypoxia, low

barometric pressure, low humidity, circadian disruption and fatigue. It has been depicted that US pilots and navigators have experienced significantly increased mortality due to cancer of the kidney and renal pelvis, and cancer of prostate , brain, colon, lip, buccal cavity and pharynx, while mortality was decreased for other causes (50). To determine if these health outcomes are related to the professional environment it will be necessary to quantify each exposure separately.

Several medications have been postulated to be benefitial softening the aging effects, including growth hormone (51), DHEAS (52) and melatonin. Antioxidant agents including vitamin C and vitamin E might play a role by lowering plasma free radical concentrations (53- 54) and improving cognitive function (55). Also substances that inhibit the AGE formation, such as the aminoguanidine, reducing the oxidative stress or destroying the already formed crosslinks may soften the progression of aging and may offer in the future new tools for therapeutic interventions in the therapy of AGEs mediated disease (5). These drugs should be further assessed before their utilization in crew members could be recommended.
There are still questions difficult to be answered. How long the crew members should be able to continue being operational?, How does aging affect one´s fitness to be operational?. The decision on when to quit active duties should be based on the physical and psychological fitness and in the selfconfidence in the abilities to do the committed missions. The NATO military crew members are included in a disciplinary piramidal structure where the higher responsabilty jobs and the decision making are currently undertaken by senior officers in most of the missions. The cornerstone of health maintenance and disease prevention is in all cases, a periodical, annual or semiannual, psychophysical examination, paying special attention to specific areas according to the mission requirements in every specific crew member assignment.

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Table 1. Life expectancy at birth in both sexes in NATO nations in 1997. Data extracted from the WHO Report 1998

Country	***Life expectancy at birth (years)***
BELGIUM	77
CANADA	79
CZECH REPUBLIC	73
DENMARK	76
FRANCE	79
GERMANY	77
GREECE	78
HUNGARY	69
ITALY	78
NETHERLANDS	78
NORWAY	78
POLAND	71
PORTUGAL	75
SPAIN	78
TURKEY	69
U. K.	77
USA	77

Table 2. Percentage of deaths in subjects under age 50 years in NATO nations.Estimation in 1997. Data extrated from the 1998 WHO Report

Country	*Deaths under age 50 (% of total)*
BELGIUM	6 %
CANADA	9 %
CZECH REPUBLIC	7 %
DENMARK	7 %
FRANCE	10 %
GERMANY	6 %
GREECE	6 %
HUNGARY	13 %
ITALY	6 %
NETHERLANDS	7 %
NORWAY	6 %
POLAND	14 %
PORTUGAL	8 %
SPAIN	8 %
TURKEY	38 %
U. K.	5 %
USA	11 %

Table 3. Current Armed Forces age policies in NATO nations and in other european nations . Survey conducted in 1999.

Country	*Minimum age of admission*	*Maximum age of retirement*
Belgium	18	51-61*
Canada	18	55
Denmark	18	60
France	18	58 (1)
Germany	17	NCO 53- OFF 60
Greece	18	60
Italy	17	65
Netherlands	17	55
Norway	19	60
Poland	17	NCO 55- OFF 58 (2)
Portugal	17	56- 64*
Spain	18	61* (3)
Turkey	NCO 18- OFF 21	NCO 55- OFF 52
U.K. Royal Army	NCO 17- OFF 19	55
U.K. RAF	NCO 16- OFF 17.5	55 (4)
U.K. Royal Navy	16	55
US Army	18	60 (5)
USAF	18	60 (5)
US Navy	18	60 (5)
Ukraine	18	50
Rep. Macedonia	23	49.5

- * Age of retirement varies with the rank.
- (1) In France the age of retirement for Generals and Admirals is 62.
- (2) In Poland the age of retirement for women is 50, and for generals 60
- (3) In Spain the age of retirement is after 33 years of Service.
- (4) Age extention is possible if fit
- (5) In the US the age of retirement is after 30 years of service.

Table 4. Operational issues of aging crew members.
National age policies on specific crews

Country	*Helicopter pilots*		*Fighter pilots*		*Submarine crews*		*Armour vehicles*	
	Admiss.	Ret.	Admiss.	Ret.	Admiss.	Ret.	Admiss.	Ret.
Belgium	18	45-56	18	45-56	-	-	18	56
Canada	18	55	18	55	18	55	18	55
Denmark	18	60	18	60	18	60	18	60
France	18	45-58	19	47-58	17-25	52-56	18	56
Germany	20	nco53-off60	20	53	20	nco53-off38	18	53
Greece	18	50	18	48	18	46	18	46
Netherlands	17	55	17	55	17	35	17	55
Norway	19	60	19	60	19	60	19	60
Poland	19	58	19	58	19	nco55-off58	19	nco55-off58
Portugal	17	56-64	17	56-64	17	56-64	17	56-64
Spain	18	50	20	50	18	40	18	56
Turkey	22	52	22	52	nco18-off21	nco55-off52	nco18-off21	Nco55-off52
Royal Army	Nco21-off19	55	-	-			nco17-off19	55
RAF	17.5	55	17.5	55	-	-	-	-
Royal Navy	18	50	18	50	16	60	-	-
US Army	18	58	-	-	-	-	18	60
USAF	22	58	23	58	-	-	-	-
US Navy	20	58	23	58	18	60	-	-

Table 5. Estimation of the percentage of NATO countries flying poplations that participate on regular exercise programmes. Data from a survey conducted in 1992 (42).

BELGIUM	30 %
CANADA	75 %
DENMARK	50 %
FRANCE	95 %
GERMANY	65 %
GREECE	20 %
ITALY	40 %
NETHERLANDS	50- 75 %
NORWAY	80 %
PORTUGAL	40 %
SPAIN	20 %
TURKEY	30 %
UK	-
US ARMY	100 %
USAF	80 %
US NAVY	100 %

Table 6. Estimation of percentage of smokers in the NATO countries flying populations. Survey conducted in 1992 (42).

BELGIUM	35 %
CANADA	25 %
DENMARK	50 %
FRANCE	28 %
GERMANY	30 %
GREECE	54 %
ITALY	40 %
NETHERLANDS	50 %
NORWAY	30 %
PORTUGAL	50 %
SPAIN	47 %
TURKEY	48 %
UK	-
US ARMY	20 % in>40y. 5%in<40y
USAF	10 %
US NAVY	20-25 %in>40y 5-10%in<40y

Human Factors Considerations of Aging Crew Members: An Overview

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Madam Chair, Distinguished Guests, Ladies and Gentlemen,

It gives me great pleasure to be with you today, in this the United Nations Year of the Older Person. I am delighted to have been asked to address you, despite some of the qualifications that have made me eligible for this honor. On the other hand - as Maurice Chevalier said – "Old age isn't so bad when you consider the alternative." As a physician and military pilot with both operational and human factors test flying experience, I have a great interest in aviation medicine. I have also been associated with this Panel for many years and was the late Professor Lauschner's vice-chairman nearly thirty years ago. This has also taught me that all of you in this distinguished audience have a critically important part to play in maintaining our NATO aircrews in a high state of efficiency over a long life span.

For some time now, demographers have been trying to tell the world that the population is growing older. Longer life expectancies, together with a general decline in the birth rate, led them to foresee a dramatic shift in the proportion of so-called "senior citizens". As we are about to enter the 21st century, the change is here and we are now only beginning to deal with the consequences. For example, in 1990 in the United States, the median age was 32.1 years, and is expected to reach 42 years by 2030[1]. We cannot continue to ignore this fact, and what is more, we must recognize that placing an arbitrary limitation of employment by age is both unnecessary and unrealistic.

As long ago as 1981, Stanley Mohler stated that, and I quote, the calendar age of 60 is no longer medically justifiable as an upper age limit for airline pilots[2]. Although we are principally interested in military aviation, I suggest that there are many reasons for addressing the operational issues that Mohler described with reference to commercial crew members. Col. Alonso-Rodriguez has already discussed many of the operational and physiological considerations related to aging crew members and I shall try to touch on some of the human factors aspects of this problem. Mohler pointed out that age alone gives no useful information about an individual's competency to carry out his flying duties, or the state of his health, and this applies to female aircrew also. He summarized three critical factors that denote fitness for flight duties: freedom from impairing disease, the ability to perform the operational duties required, and the individual's desire to continue to perform those duties. I agree with Mohler that all of these are important.

As Mohler further pointed out, the various changes to personal appearance that are associated with increasing age have no bearing upon an individual's capabilities. Indeed, as he said, many things actually improve with age, and, in this context, he stressed judgement and intelligence. Judgement is improved with experience, and older persons who are in good health tend to be less impulsive and, as a result, have better safety records. He quotes Sonnenfeld (1978)[3], who shows evidence that the performance of older workers negates the stereotyping that associates age with senility, incompetence and lack of usefulness in the labor market. Although a productive life in older age has continued for those who are allowed to realize their potential to be physically intellectually and emotionally active and productive, regrettably this is commonly frustrated by arbitrarily imposed upper age limits for employment and other functions. In terms of cognition, many of those with apparent deficits that are associated with aging are perhaps experiencing self-fulfilling prophecies. Individuals become frustrated and depressed by the various constraints that society in general, and the working environment in particular, places upon them.

I can recall a number of examples of these circular arguments that led to unnecessary frustration

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for many people. During the latter part of World War II, for example, I was a pilot on a transport squadron in the Burmese theater of operations. After a few months, we had a staff visit from headquarters and this well-meaning senior officer addressed the squadron. In what I consider to be a misguided act of judgement, he said, "As soon as Mandalay falls, you will all be going back home". Needless to say, Mandalay fell and we were as busy as ever. Not long afterwards, we had another visit from this same staff officer, who said, "Well, we had intended to get you home but, as you know, we were not able to do so; as soon as Rangoon falls, however, you will all be going home". Of course, that didn't actually happen either. I said farewell to my colleagues when the war in the Far East came to an end. These misguided briefings had quite a profound effect on the attitudes of many of my colleagues who would otherwise have been perfectly content.

When I rejoined the military, after graduating from medical school, I frequently heard the argument that 2 ½ years seemed about right for a tour of duty because in the last six months, people were not as productive as they had been previously. Surely this could also be a somewhat circular argument. When people know that their tour of duty is due to end shortly, they may feel that there is no point in starting a new project. People in older age groups, aircrew or otherwise, are frequently exposed to similar situations that can lead to frustration. However, it is not their age that is at the root of their problems so much as the way that they are treated. The ultimate frustration in my view is being arbitrarily retired because of age, despite being fit and eager to continue. As Napoleon Bonaparte once said, "Ability is of little account without opportunity." I am pleased to note that a number of major organizations are beginning to adopt a non-ageist employment policy and I hope that we shall too.

Mental capabilities and functions can be adversely affected by lack of action and perhaps mood changes such as depression due to the fact that one is full of ideas but frustrated by arbitrary rules that prevent you from carrying out productive work because of a number on your birth certificate. So, the so-called features of old age may indeed be induced by circumstances and not by degeneration. As examples of this, Mohler states that some of the more significant acts of human creativity have come from people in their seventies and eighties. In this context, he lists Tolstoy, Hugo, Verdi, Darwin, Liszt, Chagall, Monet, Michelango, Picasso, Ibsen, and Franklin. In the UK, we have the example of Bernard Shaw who was still actively creating at the age of 96. It is true, of course, that painting and writing are a far cry from flying an operational aircraft, and I don't question that. Nevertheless, if we go back to where we started, here we have a number of distinguished people who are physically capable of carrying out the job, are able to perform their work at a very high level of competence, and still remain enthusiastic to do so. One other important thing that they did have in common is that they worked in areas where there were no arbitrary age rule to stop them. Perhaps that helps to explain their enthusiasm and success.

Whether the idea of retirement in old people is a self-fulfilling prophecy, I know not. All I can say is that I am sure that there are many like me who have no wish to retire, and that concept does not enter their mind. In this context, Butler[4] has emphasized that changes brought about by disease or social stress must be separated from those which are due to normal aging. This is a very important point. He also pointed out that there was really no noticeable difference in cerebral blood flow in elderly men who were healthy from that found in twenty-year-old men who were also healthy. In 1965, Szafren[5] showed a remarkable maintenance of high mental functions in healthy older pilots who were still flying. In other studies, Spieth[6] pointed out in 1964 that pilots who had heart disease showed more deterioration in their mental function than did healthy older pilots.

Turning now to more human factors aspects of this problem, the influence of age on crew member performance is clearly a key issue in terms of operational effectiveness. As Charles Billings pointed out in 1991[7], the pilot's task is changing from what was generally manual control to more cognitive tasks such as monitoring a variety of aircraft systems and other crew members are also experiencing similar changes. These new systems involve associated decision making. It is important, therefore, to identify how such factors as age and experience influence a person's ability to perform in this increasing complex cognitive environment. Recently there have been a number of developments in this field of cognitive aging and theory of expertise which have raised important questions concerning both how and when experience mitigates against potential age decline in complex task performance. Of course, it is clear that age is only one of the many factors involved. In a sense this is what Mohler was saying, namely that declines in cognitive resources due to age may be offset by experience, the individual's state of health or other pilot-related factors. Also, other features such as task complexity and

familiarity with the task, together with stress-related environmental factors such as temperature and noise, may both make the age factor worse and minimize the advantage of experience. Although many researchers in this field would suggest that advancing age reflects a gradual reduction in the rate of both sensory motor and cognitive processing, it is not so clear as to whether this is an irreversible biological process or due to experiential factors that can be overcome by appropriate training. Some have suggested that age may cause a reduction in the cognitive resources that permit storage and processing of information in working memory, particularly if tasks involve heavy demands on storage and memory processing. Others have suggested that age may interfere with an individual's ability to ignore information that is irrelevant to the task at hand. This would have the effect of making older pilots perhaps more vulnerable to distraction. This is an interesting problem which may, however, be capable of improvement by the methods used in training crew members to carry out their complex tasks. As Rogers[8] has pointed out, "it is clear that people have learning preferences". This involves the means of presentation of information and the context in which it is being presented, and it seems that the young and old have different preferences. Perhaps there should be greater emphasis in doing so in, shall we say, a more global fashion which recognizes the need to teach people at any age how to carry out their complex task against a background of environmental stress and be mindful of how different people respond. It is clearly an issue that is commonly referred to as situational awareness and it is by no means certain that it is predominantly a problem of the elderly. Personality and experience have a significant part to play in handling what one might describe as multi-stress environments and how different individuals tackle such environments.

Even though, certain laboratory studies have suggested that age has an adverse effect on cognition, in practice it is clear that the elderly can often maintain very high levels of competence both at home and at work[9]. This would seem to be a good example of increasing knowledge and experience offsetting any declines in cognitive resources. Morrow and Leirer[9] have noted that this hypothesis is supported by the solid observations that experts out-perform novices, even though these two groups show no difference in general cognitive abilities. The so-called experts may also be less affected by age-related declines in their cognitive resources. This can perhaps be seen in several aspects of the various tasks performed by crew members.

Skill acquisition theory would tell us that certain skills become automatic with practice, therefore emphasis on sufficient and appropriate training should ensure that skills that have been thoroughly practiced would be retained with age. This is not, however, necessarily the situation for all tasks. Clearly further research should be encouraged to clarify this important issue because of its significance to the ever-changing skills that are being placed on the modern crew members. Operating a modern aircraft involves the ability to carry out multiple tasks more or less at the same time. None more so than in the military environment, where in addition to the aircraft handling, navigation, weapons system management, difficult flight conditions, and high density workloads, there is also the possibility of threat. We have already said that a key issue is whether or not the older pilot is capable of being retained in an operational setting and has the ability to perform that task to the level required. It is not always easy to come up with a measure that will allow one to evaluate performance in a global sense.

For many years, accident and incident rates and near misses have been used to assess performance. In terms of accidents, both military and civilian, there is a considerable amount of evidence available. For example, the United States National Transportation Safety Board reported that in 1,997 non-commercial aviation accidents, including 361 fatal crashes, pilots were cited as the cause or contributing to the cause of 75% of all of these accidents. In terms of those that were fatal, the percentage rose to 90%. Clearly what we loosely describe as pilot error is a very important factor in this situation. It has further been reported that the median number of hours for pilots in non-commercial accidents in 1995 was 1,040. The pilots in these cases were relatively inexperienced by operational military standards. In 1993 Kay and his coworkers[10] examined records from the United States Federal Aviation Administration and the National Transportation Safety Board in an attempt to compare accident rates for pilots of different ages and levels of experience. In general, they reported that accidents decreased for the ages 40 though 59. There was, of course, no information on accidents beyond that point because of the existence of the "age 60" limit. They also noted that recent flying experience was particularly important. This should indicate that military aviators have an excellent chance of achieving low accident rates because they usually maintain a high level of practice. Reports from the National Transportation Safety Board for the years 1970 through 1977 showed that the peak captain ages for accidents was in the forties, with a rapid fall-off to age 60, when

they were retired. One could argue that the older pilots have more experience, ability and judgement and the very fact that they have become older pilots means that they did not have an accident at a younger age. These are therefore the safer pilots. Both Booze[11] in 1977 and Mohler and his colleagues[12] in 1967 reported that the older pilot with increased experience is well correlated with decreased accidents.

In the military, the opportunity exists to add further measures of a more positive nature, such as, carrying out the task as briefed, reaching the target, identifying the target, and completing the operational mission as required. Recently, over Yugoslavia, it appears that certain crews attacked dummy wooden weapons on the ground. Perhaps this failure to identify decoys is an example of inexperience rather than poor eyesight. One very important aspect of accidents is related to the question of spatial disorientation. One could argue that the older pilot with a greater amount of experience should have a better chance of coping with spatial orientation by the very nature of his large number of hours in the air. In addition, however, training plays a very important part in this matter at all ages and must not be underestimated. Researchers tell us that experience is an important factor in overcoming declines due to age in the case of tasks that are more knowledge-based. There seems to be little evidence that older and younger pilots differ in matters due to expertise. Again, there is not a vast amount of research data on this subject. In general seems more likely to reduce perception, attention and working memory as the complexity of a task increases. Age may also have an adverse effect on the ability to perform complex communication when the task involved places a heavy load on working memory. The other side of the coin, however, tells us that age differences may be reduced by expertise when one is dealing with familiar tasks relevant to the pilot's professional domain, because highly practiced skills can be maintained into later life. Reaction time is commonly addressed when discussing the question of responses of older pilots. This is another example of a physiological age-related response that is not at all easy to quantify in terms of the aircrew task. It is perhaps misleading to measure reaction time in isolation because, in practice, what is critically important is that the crew member reacts correctly to whatever is the initiating stimulus. Experience can play an important part in offsetting any decrement in response due to age.

Another interesting aspect of pilot performance that should perhaps be addressed is the significance of personality variables. Siem and Murray[13] published a paper on this subject in 1994. They suggested that, in general, the research literature seems to suggest that personality variables play little part in pilot performance. In their opinion, one reason for this is the inability to find stronger links due to what they called the lack of appropriate taxonomies for both personality and performance constructs. They examined the relationship between certain personality factors and combat performance using the so-called "big five" model of personality which was published by Goldberg[14] in 1992. These were: extraversion, agreeableness, conscientiousness, emotional stability, and openness to experience. Siem and Murray related these factors to a multi-component model of pilot combat performance. In their study, 10 United States Air Force pilots rated the importance of 60 traits for effective performance of such capabilities and crew management. Interestingly, they indicated that the responses from pilots who had different aircraft backgrounds all agreed that the personality trait that was the most important measure of performance overall was conscientiousness. This brings us back once more to the original requirements described by Mohler in which he stressed the importance of motivation to continue in the role and one could reasonably argue that conscientiousness represents an important part of motivation.

In summary, the more one digs into the literature, be it clinical or human factors related, the more one finds that there is really no hard evidence on which to make a definitive judgement on this interesting and complex matter of age and flying. It seems reasonable to interpret this to mean that there is equally no solid evidence to say that there should be an arbitrary age beyond which no crew member should be allowed to continue to fly, whether military or civilian. In terms of skill retention, researchers have reported how skills that have been acquired at a young age are retained into old age, and surely that applies to aircrew tasks. We must not ignore the important issue of individual differences, however. Our knowledge of human abilities in carrying out different tasks is quite incomplete if we ignore the existence of individual differences. Stepping aside from flying for a moment, a similar situation, and one which is on a much greater scale, is that of driving, and the question of which older drivers should be allowed to drive and which should not. If one were to adopt a totally arbitrary situation, then no one over the age of 65 would be allowed to do so. Clearly that is not a reasonable solution, because of individual differences, and I suggest to you that it is equally not reasonable to use an arbitrary age limit to for pilots or other crew members. Our duties are to

ensure that we should be addressing specifics and not generalizations.

What does all this mean? Well, I think that we have established that whatever system we use must be based on the fact that we are dealing with individuals, and that not all individuals will reach the end of their efficient flying careers at the same age. Our problem, therefore, is to address both the mental and physical abilities of each and every individual and monitor them carefully throughout their professional career. Before I comment on that subject, however, I would like to touch upon an issue that I believe is fundamental to the effectiveness of any such system and that is the relationship between the individual aircrew member and those who are carrying out this monitoring function. It was my experience when I served as a Flying Personnel Medical Officer in the Royal Air Force that many members of aircrew had the feeling that the purpose of the medical branch was to find reasons to ground them. Clearly, nothing could be further from the truth, but nonetheless such an attitude of mind is unfortunate to say the least and ultimately can be very dangerous. I suppose that this attitude is understandable to some extent in any system wherein an individual's whole future depends upon obtaining a satisfactory medical clearance every year. Out of ignorance of their true medical condition, some people may hide symptoms for fear of being grounded, and by so doing, simple problems can become serious and even life threatening. Where does the system fail and what can we do about it? In my view it is essential to ensure that the medical staff create and maintain a supportive attitude with crew members in terms of their medical cover. I believe this can be achieved if the medical role is seen in a more preventive light rather than being entirely curative. It requires a bond between the aircrew and those who looking after them, that encourages trust and the true belief that the medical team is going to do their utmost to help them to remain active crew members as long as possible, irrespective of their age. This attitude will be greatly fostered when there is no arbitrary administrative age limit in terms of an individual's career.

There is some difference of opinion in the literature as to the significance of age in terms of critical areas of cognitive performance. I believe, therefore, that we must make efforts to follow an individual's cognitive history throughout his career by means of his or her training records be they related to performance in the air or in simulators, and look carefully for any signs of degradation and the underlying reasons. At the same time, those of us working in the field of human factors should take note of the various aspects of cognition that may be affected by aging. We should also take advantage of all the positive evidence presently available that better training, better instrument layout, perhaps different communication systems, can optimize individual abilities. In addition we should continually strive to further improve the lot of all crew members by developing better and more user friendly working environments. As Kantowitz and Sorkin[15] have written, the first edict of human factors is "Honor Thy User". That does not only mean improving the ability of the aging pilot, this important concept will have a beneficial effect on crew members of all ages.

Apart from the purely cognitive component, we must also address the issue of physical limitations with age. I am sure that most of you have heard criticisms by pilots about physical fitness and measurements of physical fitness. Personally I recall such statements as "Why do I have to do all this, doc? I'm going to fly the airplane, not carry it!" Some years ago I recall that the Royal Air Force aviation physiologists tried to rectify this by changing both the ways of measuring performance and the situations in which they were measured. I felt that this was a good idea, because crew members would have fewer complaints if the fitness measures bore a closer relationship to the operational task. In addition, routine physicals should address all the measures that are well established as to an individual's state of health and these we have already heard about today from our colleague Colonel Alonso-Rodriguez. However, I also believe that we should look at those medical examination results in the same way that I described for training results, namely as a longitudinal study. In that way, we will get better indicators from both types of datasets that will tell us whether there are any significant changes occurring to this individual. This approach to medical data will also permit distinctions to be made between standards that are required for entry into an aircrew training program, and standards that are acceptable as the individual becomes more and more experienced. I am sure that all of us can think of limitations that are acceptable for continuation of flying but would not perhaps be acceptable for entry into such a career program. All of these factors should contribute to the concept that the system is being tailored to individual needs for aircrew of all ages as a means of increasing efficiency. At the same time, by keeping an eye on individual performance, one can find out at the earliest possible stage if medical or physical intervention can help an individual to continue a fruitful career. I don't wish to get into the area of

retraining crew members for different roles, that is a matter for our current operator colleagues. I mention it, however, as another example of looking at all aspects of this problem. By the time an individual becomes an experienced crew member, in whatever role, he or she represents an enormous investment in time and money as far as the military is concerned. I think that it is only sensible and practical to look at the big picture and do whatever one can to take advantage of that individual's experience.

So, in conclusion, today's safe professional operational crew member should be one who is free from disease which could impair his or her task; one who is capable of performing all that is required of the operational appointment; and one who is keen to continue to carry out that task to the best of his or her ability. In addition, we should bear in mind, not only for the older aircrew but for aircrew of all ages, that we can do much to make the their task more efficient and safer by the way we design their workspaces and carry out their professional training. Finally, we should make every effort to be positive and supportive so that crew members will continue to be productive and contribute their experience to the operational effectiveness of NATO, unhindered by arbitrary age limitations. To put two quotes together, the first part from Les Brown, the second part from Robert Browning (in a different era), "You are never too old to set another goal or dream a new dream. Grow old with me – the best is yet to come."

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THE EFFECT OF AIRCREW AGE ON +Gz TOLERANCE AS MEASURED IN A HUMAN-USE CENTRIFUGE

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INTRODUCTION

Pilots of high performance military aircraft are often exposed to positive acceleration stress (+Gz). This type of acceleration displaces blood in the head to foot direction. As the pressure in the vessels of the lower body increases, the vessels dilate, and a major portion of the blood from the upper part of the body is translocated to these lower vessels. The pooling of blood in the lower extremities translates into reduced cardiac output provoking the cardiovascular system, mainly by the activation of baroreceptor reflexes, to maintain adequate blood flow to the central nervous system (CNS) and thereby maintain normal brain function (1, 3, 11).

The physiologic symptoms of acceleration stress range from petechia hemorrhages (burst capillaries present in the limbs) to loss of vision and ultimately loss of consciousness with potential fatal consequences when it occurs in flight (1, 6, 11, 21). Mission effectiveness may also be affected by +Gz stress in that the lack of adequate blood flow to the CNS leads to degraded motor and cognitive performance. This degradation may then lead to aircraft accidents and incidents commonly labeled "pilot error." Hence, aircrew are routinely trained in the human-centrifuge to understand and better tolerate +Gz stress (10, 12, 18, 19).

A data repository was formulated in 1988 to compile information on aircrew who underwent acceleration tolerance training at the Naval Air Warfare Center (NAWC), Aircraft Division human-use centrifuge in Warminster, PA, USA. This program was known as the G Tolerance Improvement Program (GTIP) and was coordinated by personnel of the Crew Systems Technology Department of NAWC. The trainees participating in the program included members of the US Navy, Marines, and Air National Guard.

There is a concern that as the aircrew becomes older, their flight performance may not be adequate. Since tolerance to +Gz-stress is to a large extent dependent upon a healthy cardiovascular system, the propensity for increased vascular disease in individuals older than 35 yr. may indicate a reduced ability to tolerate repeated bouts of high +Gz-loads (17). Also, reaction time may slow down. For example, it has been estimated that the total time a pilot flying a 1,800 mph aircraft has to initiate a control sequence change in response to suddenly sighting another aircraft can be as long as 1.7s as follows: 0.3 s for visual acquisition, 0.6 s for recognition of impending danger, 0.5 s to select course of action and 0.3 s to initiate the desired control response (13). Given the response time of the aircraft, if the two planes were less than 4 miles apart, any response would be futile. Therefore, as reaction time slows, so does mission effectiveness. Measures of isometric strength also reduce with age, falling to 90 – 95% of maximum at 40 yr., 85% at 50 yr., and 80% at 60 yr., though not all strengths decline at this rate (e.g. back strength falls more rapidly, (14)). In response to these concerns, the US Navy acceleration research program limits subjects to 40 yr. and US aviators are relieved from flying at 60 yr. unless exempted by special wavier.

The purpose of this paper is to present data as it relates to aging and mission deficiency. Specifically, the relationship of age and acceleration tolerance as measured in a human-use centrifuge.

BACKGROUND

The purpose of the data repository is to improve +Gz-training methods and establish a large sample source of aircrew G tolerance characteristics. The repository consists of three sections structured in accordance to Microsoft® Access (Redmond, WA, USA) format. These sections are 1) trainee description; 2) +Gz profile description; and 3) cardiovascular response of the trainee to that +Gz profile. The first two sections are obtained from Run Sheet forms completed by the trainees and training personnel. The latter section is obtained from review of the trainee's electrocardiogram (ECG) which included 2 channels of ECG data based on sternal and biaxillary lead placement. These

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records are compiled for later review and entry of cardiovascular data into the database. All trainees considered for this paper either passed the appropriate physical examination requirements required for flight duty (Class I or II) or were determined to be fit for +Gz exposure by a qualified physician prior to insertion in the centrifuge.

The GTIP training protocol consisted of an approximately 2-hour lecture on the effects of +Gz stress on human physiology and the methods to combat this stress. Following this lecture each trainee was exposed to the acceleration environment in the human-use centrifuge for approximately 15 minutes. This device has been described in the literature (2, 5). While trainees underwent training in the centrifuge, their classmates witnessed the sequence of events thereby allowing them to learn from others and discuss the various techniques to better withstand +Gz. The GTIP program does not include a pass/fail valuation within its training protocol. However, the competitive nature of aircrew was evident. Upon termination of the +Gz exposure, each trainee was debriefed signifying the completion of the training day.

Technology to help combat acceleration stress includes the anti-G suit (AGS). The AGS is a protective garment used by aircrew to enhance tolerance to +Gz forces experienced in high performance aircraft. The AGS is a pair of trousers composed of inflatable air bladders strategically located over the calves, thighs, and abdominal areas. The subject dons the AGS, which is connected via a hose to an anti-G valve. The suit is activated in accordance to G exposure level. Activation of the AGS (inflation of the air bladders) exerts pressure against the lower limbs and abdomen. This pressure aids the cardiovascular system to maintain adequate blood flow to the CNS by forcing blood towards the head "counteracting" the effect of +Gz (3). Benefits of the AGS include increased G tolerance (G level), increased G exposure duration, and reduced petechia hemorrhage incidence. The AGS also aids the wearer to perform anti-G straining maneuvers (AGSM) as it provides the subject something to "strain against" and decreases the fatigue mostly generated by this effort. Resting G-tolerance levels as defined by loss of peripheral vision have been reported to average 3 G without and 4.5 G with an AGS.

The AGSM provides further protection against +Gz stress as follows. The "L-1" AGSM combines a periodic, 3 s strain (valsalva) against a closed glottis. A rapid exhalation and inhalation of < 0.5 seconds interrupts this strain. Tensing of all major muscle groups of the abdomen, arms, and legs is part of the effort. The AGSM provides an average 1.5 G protection above resting G tolerance levels (with AGS). This maneuver is also known as the "Hook" maneuver where the subject says the word "hook" as s/he begins to strain thereby ensuring a completely closed glottis. Other maneuvers include the "M-1" (partially closed glottis) and the Qigong (Q-G) Maneuver (10, 20, 22).

The GTIP profile included several exposures to +Gz. This paper discusses the gradual onset rate exposure portion of this profile as this exposure provides a measure of baroreceptor reflex response to the stress under discussion. Rapid onset rate profiles were also examined in that these better reflect the actual flight environment.

METHOD

A gradual onset rate (GOR) exposure was the first of a series of +Gz runs during a single GTIP training day. The GOR exposure commenced at a resting level of approximately 1.0 +Gz and increased at 0.1 G/s. Visual decrement was subjectively assessed by the trainees' inability to see an array of light emitting diodes (LEDs) placed in an arc describing 15° increments (150° total) 30 cm in front of the subject at eye level. The run proceeded until the trainee experienced 60° Peripheral Light Loss (PLL1), i.e., vision was confined to an arc describing 30° either side of the central point directly in front of the trainee. Once PLL1 was reached, the trainees were instructed to perform AGSM until peripheral vision was once again reduced to 60° (PLL2). The trainees then terminated the +Gz exposure by pressing a pre-selected button located on the control stick. The limit of the +Gz exposures was 9 +Gz. The profile was "open-loop" in that the trainee was not in control of the device but could stop the run at any time. A standardAGS was worn and activated during the +Gz exposure. This suit was either the CSU-13B/P or CSU-15B/P. There are no significant differences between these two suits. The inflation rate of the suit is approximately 1.5 pounds per square inch (psi) per +Gz. Inflation of the AGS bladders started at approximately 2 +Gz to a total of 11 psi when fully inflated at 9 +Gz.

The GOR exposure was followed by a series of rapid onset rate (ROR) exposures. The ROR exposures commenced at a resting level of approximately 1.0 +Gz. +Gz then increased at approximately > 6.0 G/s (haversine profile) until reaching a predetermined plateau level ranging from 5.0 to 9.0 +Gz. The plateau was to be maintained for a period of 10, 15, or 30 s. Both the G level and the plateau duration depended on the protocol of the time. That is, the protocol for the ROR exposures changed over the five years of training exercises under discussion. The ROR exposures were performed in sequence where the G level was increased by 0.5 or 1.0 G depending on the trainee's performance as the training exposure progressed. Most trainees experienced a total of four ROR exposures to 5, 7, 8, and 9 +Gz. The rest period between the runs was 1 minute or more. This period allowed the trainees to return to a resting heart rate similar to the one immediately prior to commencing the training runs. The AGS was worn and activated during the entire ROR

exposure. The trainees were instructed to perform AGSM throughout these exposures. The ROR profile was also open-loop. Reasons for GOR and ROR run termination included 60° light loss, pain, fatigue, and G-induced Loss of Consciousness (G-LOC). Otherwise, the run was considered as "completed."

The centrifuge's cockpit configuration was similar to the F/A-18. A qualified physician monitored all exposures. Two channels of ECG activity were recorded during all runs (sternal and biaxillary lead placement).

The variables selected for GOR analysis were the subject relaxed +Gz tolerance as measured by PLL1; the subject straining tolerance (PLL2); and the protection afforded by the AGSM (PLL2 - PLL1). Incidence of G-LOC was also examined. Resting heart rate (RHR), maximum heart rate (MHR), and recovery heart rate (RCVHR) in beats per minute (bpm) available from 19 trainees were also examined to determine the effect of age on baroreceptor response to +Gz and recovery from the same. The variables selected for ROR analysis included G plateau duration and reason for run termination. Unfortunately, sufficient physiologic data were not available from these trainees for statistical analysis.

Statistical analysis included analysis of variance and multiple regression methods. Post-hoc analysis was performed as necessary. The null hypothesis is summarized as follows: "H_o: Age does not demonstrate to have a significant effect on G-tolerance as measured by the variables selected for this retrospective study." Level significance was selected as $\alpha = 0.05$. The statistical software used for data analysis was NCSS 2000© (Kaysville, UT, USA).

RESULTS

Information on 1,120 aircrew (74% pilots) who underwent acceleration tolerance training at the Naval Air Warfare Center human-use centrifuge was compiled. High performance aircraft was represented by 95% of the trainees (attack, 38%, fighter, 57%). Table 1 describes the aircraft type distribution of this sample. The repository included information on trainees from the US Navy/Marine Corps (70%) and Air National Guard (30%).

Table 1. Aircraft Type represented by 1120 GTIP trainees.

A4	A6	A7	AV8	A10	A37	F1	F2	F4	F14	F15	F16	F18	Other	Unknown	TOTAL
19	126	71	48	105	52	13	53	62	200	34	86	187	26	38	1120

Balanced GOR response data from 817 trainees were selected for further evaluation. The mean age (± S.D.) of this group was 31.4 ± 6.8 years (20 to 59 years). Figure 1 describes the age distribution of this sample. Trainees included 79% pilots; 14% "backseaters" (BS) such as weapons or radar intercept officers; 3% Flight Surgeons (FS); and 2% Physiologic Training Officers (PTO). The remaining 2% (n= 18) of the trainees did not specify their flight status. Table 2 describes their respective age distribution. Age was significantly different among the four groups (F=28.02, p<0.000) where the largest difference was that between FS and BS by approximately 11 years. Figure 2 describes this finding.

Table 2. Age distribution by trainee type (n= 799).

Value	Pilot	BS	FS	PTO
Mean	31.79	27.08	38.52	32.94
S.D.	6.67	3.63	10.76	5.66
number	642	118	23	16

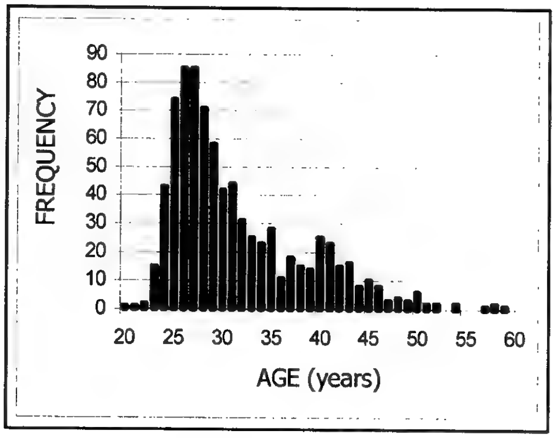
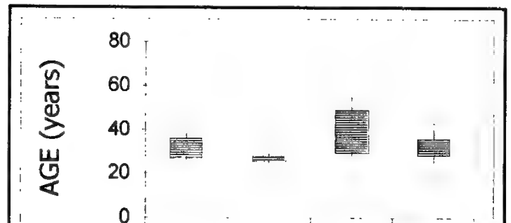


Figure 1. Age distribution of 817 GTIP trainees.



	Pilot	BS	FS	PTO
75%ile	36	28	49	36
max	58	40	59	45
min	20	22	27	24
25%ile	27	25	29	28

Figure 2. Distribution by flight status (n=799).

Of the 817 trainee-sample, 52 were smokers (≥ ½ pack per day). Their age (23 to 50 years) did not differ from non-smokers (33.3 ± 7.3 years). Eighty-five percent of the smokers were pilots (n=44), 10% were BS (n=5), and the remaining 5% represented 1 FS and 2 trainees whose flight status was unknown.

An analysis of the relationship between the amount of experience with +Gz-stress in flight and tolerance to GOR centrifuge exposures was conducted. It was found that the number of total and tactical flight hours as well as the number of flight hours during the 30 days prior to the training exposure did not affect +Gz tolerance.

Relaxed GOR tolerance was 4.9 ± 0.9 +Gz (n=817). Age did not demonstrate to have an effect on this tolerance (F=4.43, r^2=0.005). Figure 3 depicts the regression residuals and the predicted values of relaxed G tolerance as measured by PLL1.

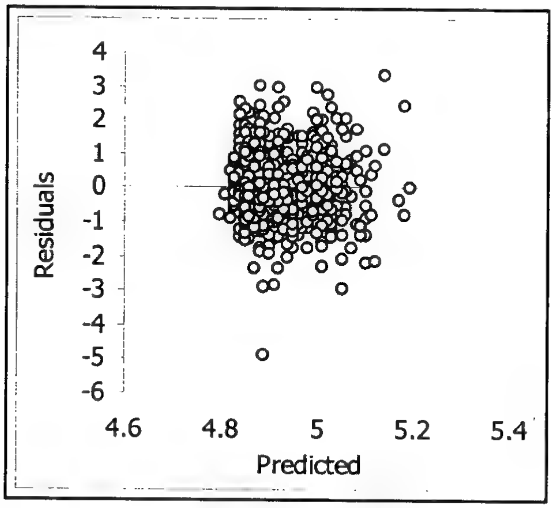


Figure 3. Age and +Gz tolerance as measured by PLL1.

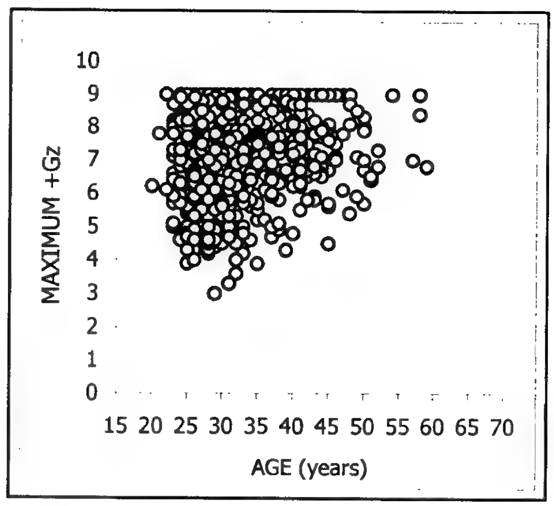


Figure 4. Age and +Gz tolerance as measured by PLL2.

Figure 4 demonstrates the relationship between age and +Gz tolerance as measured by PLL2. Straining tolerance was 7.2 ± 1.3 +Gz (n=817). Age did not demonstrate to have an effect on this tolerance (F=14.59, r^2=0.017). The protection afforded by the AGSM was 2.7 ± 0.8 +Gz (0.5 to 6.0 +Gz, n=674) and was not affected by subject age (F=5.40, r^2=0.007).

Of 896 complete GOR trainee data sets addressing the reason for run termination, 91% (n=817) were terminated for normal reasons (i.e., PLL); 7% (n=59) were terminated due to G-LOC, and 2% (n=20) were terminated for other reasons (i.e., centrifuge computer safety stop, other technical reasons, etc). Age did not demonstrate to have an effect on G-LOC incidence. Table 3 compares the incidence of G-LOC and normal run terminations.

Table 3. Incidence of G-LOC and normal +Gz exposure termination and percentage of total per age group.

AGE	Normal	%	G-LOC	%
25	136	*92.5*	11	*7.5*
26-31	385	*93.7*	26	*6.3*
32-37	136	*92.5*	11	*7.5*
38-43	108	*94.7*	6	*5.3*
44-49	36	*90.0*	4	*10.0*
50-55	12	*100.0*	0	*0.0*
56-61	4	*80.0*	1	*20.0*
Total	817		59	

Exposures where heart rate data was analyzed (n=19) ranged from 5 to 9 +Gz (5.5 ± 1.3 +Gz). The mean age representing this data set was 34.8 ± 8.9 (23-52 years). The change described by MHR-RHR was 57 ± 21 bpm. The change described by MHR-RCVHR was 69 ± 27 bpm. The difference was statistically significant (t=3.09, p=0.006). Multiple regression demonstrated that age and the +Gz level at which the MHR occurred (GMHR) explained 52% percent of the variability in MHR-RCVHR (r^2 age = 0.33, $pT_{\beta 1}$= 0.001; r^2 GMHR= 0.51, $pT_{\beta 2}$= 0.027). The model was described by MHR-RCVHR= 64.12 – 2.03*age + 10.68*GMHR (F=8.51, p=0.003, power = 0.66). All recovery heart rates were noted within the first 75 s. Figure 5 depicts this relationship at various +Gz levels.

Similarly, no statistically significant relationship was found when the change MHR-RHR was considered with respect to age and GMHR. However, simple regression examination of residuals appeared to delineate two separate age groups as follows. The change MHR-RHR appeared to increase with age for trainees ≤ 34 years old (r=0.56). The same was true for MHR-RCVHR (r=0.60). However, regression analysis did not demonstrate statistical significance. The change MHR-RHR was higher for trainees ≤ 34 years old (69 ± 19 bpm) than for trainees 37 to 52 years old (44 ± 14 bpm). This 25 bpm difference was significantly different (t=3.10, p=0.006). The change MHR-RCVHR was higher for trainees ≤ 34 years old (88 ± 22 bpm) than for trainees 37 to 52 years old (49 ± 15 bpm). This 39 bpm difference was significantly different (t=4.5, p=0.000). Figure 6 describes these findings. The larger symbols represent the 5 smokers in this sample.

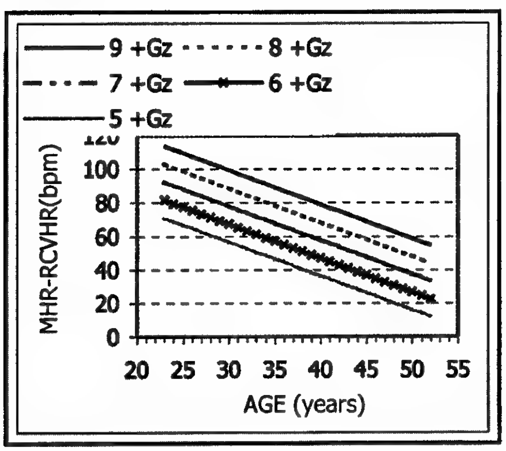


Figure 5. Change from maximum heart rate to recovery heart rate after exposure to various +Gz levels.

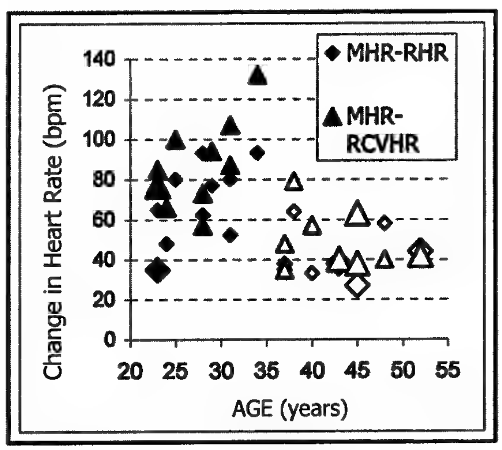


Figure 6. Change from in heart rate from maximum during +Gz exposure and its rest level.

For the purposes of this paper, examination of the ROR exposures concentrated on individuals aged above 49 years. Eighteen trainees' data were analyzed. Their flight status was 11 pilots, 6 flight surgeons, and 1 trainee who did not provide this information. One of the pilots was a smoker (for 30 years). Table 4 presents these trainees' characteristics.

Table 4. Characteristics of 18 trainees over 49 years of age.

n=18	AGE	Total Flight Hrs.	Tactical Flight Hrs.	Height (in.)	Weight (lbs.)
Minimum	50	30	0	65.0	145.0
Maximum	61	25000	6000	76.0	215.0
Average	53	4418	2412	70.4	183.7
Standard Deviation	3.8	5854	2156	2.6	18.4

Age did not show to have an effect on the trainees' ROR tolerance in that their progress through the training protocol was similar to those of age less than 49 years. Performance of the trainees, including those over 49 years of age, did not seem to be affected by ROR run-number sequence. Data was available from sixteen of these oldest trainees. Specifically, for the second run of the training day, fifteen of these older trainees completed their run successfully (6 +Gz plateau for 30 seconds). For the third run of the training day, data was available from 16 of these trainees. Thirteen of these older trainees completed their run successfully (ranging from 5.5 to 8 +Gz for a plateau duration of 15 or 30 seconds). For the fourth run of the training day, data was available from 13 of these trainees. seven completed their run successfully (ranging from 7 to 9 +Gz for plateau duration of 15 seconds). For the fifth run of the training day, data was available from 13 of these trainees. Seven of these older trainees completed their run successfully (ranging from 7 to 9 +Gz for plateau duration of 10 or 15 seconds). Finally, two of the trainees continued on up to completing an eighth ROR exposure successfully (up to 10 seconds at 9 +Gz, ages 50 and 51). All of theROR exposures which ended prematurely were due to light loss, fatigue, etc., except for two exposures which were terminated due to G-LOC (both during the 5th run of the training day). Incidence of light loss, fatigue, etc. was similar for all age groups (20 – 60 yr.).

The reasons trainees gave for run termination were not related to age regardless of exposure type (GOR or ROR) or +Gz level achieved (5 to 9). Examination of the totality of the data repository yielded 4,746 exposures. 3,280 runs were completed (70%) while 271 incomplete runs were due to G-LOC (5%) (terminated by an observer) and 1195 (25%) were halted by the trainee for other reasons. Table 5 presents the data in accordance to the trainees' age range.

Table 5. Breakdown of outcome of training runs by age range, completion, or incompletion (G-LOC or other reason) (p= percentage of age group, n= number).

AGE	Runs by age (n)	Completed runs (n)	Completed (p)	G-LOC (n)	G-LOC (p)	Other incomplete (n)	Other (p)
< 29	2241	1575	0.70	125	0.06	541	0.24
< 39	1720	1170	0.68	104	0.06	446	0.26
≤ 49	707	486	0.69	39	0.06	182	0.26
> 49 - 61	78	49	0.63	3	0.04	26	0.33
Totals	4,746	3,280		271		1,195	

DISCUSSION

Acceleration stress effects on human physiology have been studied since the 1930's. The first protective response against +Gz forces is a series of reflex cardiovascular changes. Upon exposure to +Gz stress, there is an immediate hydrostatic pressure drop from the aorta to the carotid sinus generating a simultaneous stimulation of the vasomotor center. This action results in vasoconstriction, increased blood pressure, increased contractility and a rise in heart rate. Reflex tachycardia occurs in an effort to normalize the blood supply to the brain and other tissues. Simultaneously, the vasomotor center and other areas of the reticular formation transmit impulses to the abdominal muscles resulting in higher muscle tone and contraction of abdominal viscera. These events compress the abdominal venous reservoirs to translocate blood out of the abdomen toward the central circulation (11). Anxiety, AGSM, and the AGS enhance these protective measures.

The characteristics of the ECG response to +Gz exposure have also been reported in the literature. Heart rate increases in anticipation of the exposure and subsequently with G level. Heart rate then returns to its resting state approximately one to two minutes after the exposure. Heart rate does not predict +Gz tolerance but it is monitored to assess an appropriate response to the stress. There is a greater change in heart rate per +Gz level as acceleration increases during gradual onset runs than rapid onset runs. This change is reduced by 50% as the onset rate increases from 0.1 G/s to 1.0 and 6.0 G/s (4, 7-8, 16).

The difference in age relative to flight status was not surprising. Number of flight hours also showed a difference with age as expected. Note that flight hour experience, including flight hours during last 30 days prior to the exposure did not affect +Gz tolerance. During the training lecture, trainees were told that G-tolerance was reduced as time between +Gz exposures increased. In the development of the NAWC centrifuge subject pool, it was found that subjects needed G exposures on at least a monthly basis to maintain a consistent behavior in the centrifuge. A USAF study of this relationship found that while relaxed GOR tolerance was unaffected after a four week layoff, G endurance tolerance was significantly reduced (15). This reduction was attributed to a lack of recent practice with the AGSM. The USAF study did not address the effect of layoff on straining tolerance to gradual or rapid onset exposures. One factor not addressed in the present study was the relative quality of the trainees' AGSM. The concern that effective G-tolerance (with protection) will degrade without practice and recent +Gz exposure has led the US Navy training centrifuge staff at Lamoore, CA to consider having pilots return to the centrifuge for annual refresher training.

The greater change in RHR-MHR in the younger trainees is probably related to their overall lack of experience in the high +Gz environment and the anxiety typically associated with first centrifuge exposures. In the human-centrifuge training environment, as compared to an aircraft, pilot are passive riders rather than in active control of the +Gz-load. The younger trainees may have demonstrated a more emotional response than their older peers with possibly higher levels of circulating norepinephrine. The difference in change in heart rate past age 35 is difficult to interpret since the data is confounded by the smoking variable. Also, time of heart rate recovery was not noted in this preliminary analysis. The increased sympathetic activity expected of smokers has been reported to mask the parasympathetic response typically observed during recovery from GOR exposures (9).

It would be expected that the decrease in maximal breathing capacity and the reduced muscle mass and therefore muscle power with age affect physiologic response to stress. Also, vascular tone along with other related parameters that may affect peripheral resistance typical of the aging process may reduce this response. Cardiac output itself is reduced as much as 50% from the teens to 80s. However, this assertion is based on data derived from the general population. It does not take into account that aircrew are not sedentary, are generally in excellent health and free of disease, and are not older than 60 yr. Individuals in the database included in this study all successfully passed Class I and II flight physicals and were healthy. In the case of both the GOR and ROR exposures, subjects demonstrated appropriate, uneventful and successful cardiovascular responses to +Gz stress seemingly unrelated to age. In fact, the infrequent incidents of G-LOC all resolved uneventfully.

This study focussed on ECG responses to GOR exposures because they have been shown to provoke a significantly greater cardiovascular response than rapid onset exposures. However, aviators rarely, if ever, experience such prolonged slow onset rate +Gz exposures in flight. Aircrew may be exposed to onset rates of 6 G/s or higher during repeated maneuvers over the course of a mission. G tolerance is a global term that has various subcategories. Cardiovascular G tolerance refers to the ability of the heart and vasculature to counteract the effects of +Gz-stress over time (typically 10 to 15 s). This is typically determined using GOR exposures. Neurologic G tolerance refers to the ability of the central nervous system to resist +Gz stress over a period of 5 to 7 s (the buffer period afforded by oxygen present in the cerebral tissues at +1 Gz). Rapid onset exposures (≥ 3 G/s) are used to assess this tolerance. G endurance tolerance refers to the ability to maintain vision and consciousness during repeated bouts of high +Gz-stress. This tolerance is assessed through the use of simulated aerial combat maneuvers in which alternating levels of +Gz stress are repeated until subjects are exhausted.

The training scenario experienced by these trainees did not address their level of G endurance tolerance. Of recent interest is the effect on G-tolerance of transitions between less than +1 Gz to greater than +1 Gz (known as the "push pull" effect, PPE). The database contains exclusively positive Gz exposures. It is unknown whether tolerance to repeated or PPE type exposures is affected by the age of aviators. Given the operational nature of these exposures, additional study is required to completely address the issue of age and G tolerance.

CONCLUSION

Based on the variables examined in this retrospective study, there does not seem to be a significant effect of age (20 – 61 years) on tolerance to gradual and rapid onset +Gz exposures as measured in the human-use centrifuge.

ACKNOWLEDGEMENTS

The contents of this paper would not have been possible without the cooperation of the trainees who underwent acceleration exposures in the Warminster centrifuge. We thank them for their support. Members of the Naval Air Warfare Center, Crew Systems Technology Departmentwere invaluable in the compilation of the data reported herein. Their patience and enthusiasm is appreciated.

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EVALUATION DE L'EFFET DU VIEILLISSEMENT DES EQUIPAGES SUR LES CONSEQUENCES DU DECALAGE HORAIRE

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RESUME

Introduction : L'effet du franchissement rapide de plusieurs fuseaux horaires entraîne chez le personnel navigant et militaire des perturbations des rythmes gouvernés par l'horloge biologique. Il en résulte un syndrôme de désynchronisation plus ou moins marqué selon les individus. L'asthénie et les troubles du sommeil constituent les signes classiquement retrouvés auxquels peuvent s'ajouter des baisses de performances cognitives (attention et mémoire) et des dégradations des capacités physiques (puissance et endurance).

Le propos de cette étude est de rechercher un éventuel effet de l'âge sur la sensibilité individuelle au décalage horaire.

Méthodes : La recherche de l'influence de l'âge est réalisée dans le cadre d'une étude franco-américaine plus vaste appelée Opération Pégase, dans laquelle la resynchronisation des rythmes biologiques et l'effet du décalage horaire sur les performances opérationnelles des sujets sont étudiés.

Neuf sujets ont subi, dans des conditions opérationnelles militaires et sans aide pharmacologique, un décalage horaire de sept fuseaux suite à un vol vers l'Est. L'effet âge est évalué sur des tests caractérisant la vigilance et l'humeur des patients (Echelle Visuelle Analogique, Agenda de Sommeil, Fréquence Critique de Fusion Lumineuse), un test d'attention (Barrage de Signes), et des tests de performances physiques (force de poigne et détente verticale). Chaque test est réalisé le matin et l'après-midi des dix jours suivant le décalage horaire.

Résultats : Les sujets présentent un âge moyen de 37 ± 8,2 ans. Ils sont répartis en deux groupes : les sujets de moins de 35 ans et les sujets de plus de 35 ans.

Il n'y a pas d'effet âge sur les différents tests de performances physiques ainsi que sur le test d'attention.

L'effet âge est quasiment inexistant sur le test de la Fréquence Critique de Fusion Lumineuse permettant d'évaluer l'éveil cognitif du système nerveux central. Concernant le questionnaire de l'Agenda de Sommeil, autre test de vigilance, les sujets jeunes ont une qualité subjective de sommeil moins bonne que les vétérans, au cours des deuxième, huitième et neuvième nuits suivant le décalage horaire.

L'effet âge sur l'humeur des sujets n'est apparent que du deuxième au cinquième jour. Le matin du deuxième jour, les vétérans se sentent mieux que les jeunes, dans dix items sur seize explorés dans les Echelles Visuelles Analogiques. Ce sentiment se retrouve les quatrième et cinquième jours, mais de façon plus limitée. Une sensation d'ennui des vétérans est à noter au matin du huitième jour.

En ce qui concerne les pressions artérielles et fréquences cardiaques mesurées, les vétérans présentent de façon discontinue, une fréquence cardiaque orthostatique plus faible que les jeunes.

Conclusion : L'influence du facteur âge apparaît modérée sur la vigilance du sujet mais il présente un impact plus important sur l'évaluation personnelle de l'humeur, surtout marqué aux deuxième et cinquième jours, tout en n'étant pas discriminant sur les performances physiques et cognitives.

Ainsi, cette expérimentation réalisée dans des conditions de déploiement opérationnel de troupes ne confirme pas globalement les données de la littérature. Les sujets plus âgés, peut-être en raison de leur expérience, ne semblent pas être réellement pénalisés dans le cadre expérimental choisi.

1• INTRODUCTION

Au cours des vols de longue durée, les pilotes civils mais aussi militaires sont sujets au décalage horaire. Les symptômes sont différents pendant les vols militaires, par exemple, pendant le déploiement de troupes, du fait du stress et du manque de confort.

Avant d'étudier les effets de ce type particulier de décalage horaire et d'évaluer ses conséquences avec le vieillissement et du fait de la relation entre vigilance et sommeil, nous ferons un rappel des modifications physiologiques du sommeil liées à l'âge. Nous poursuivrons par la présentation d'un exemple de syndrôme de décalage horaire en situation militaire, et concluerons par quelques recommandations.

2• MODIFICATIONS PHYSIOLOGIQUES LIEES AU VIEILLISSEMENT

Les principales dégradations qui se produisent à partir de 35 ans sont une diminution de l'amplitude des rythmes circadiens, une avance de phase et un raccourcissement de période des rythmes de la température, de la mélatonine et du cycle jour-nuit, une augmentation des latences d'endormissement et des stades 1 et 2, une diminution du sommeil lent et une fragmentation du

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sommeil paradoxal (augmentation des éveils nocturnes) (2, 10, 12). Ces phénomènes peuvent s'expliquer par une réduction de la sensibilité de la rétine à la lumière et par des modifications morphologiques et chimiques du noyau suprachiasmatique et de l'épiphyse (diminution de la sécrétion de mélatonine). La mauvaise qualité de sommeil qui en résulte, affecte les performances et l'humeur des sujets.Une étude détaillée des modifications du sommeil au cours du vieillissement sera exposée dans une autre présentation de ce colloque.

3• LE SYNDRÔME DE DECALAGE HORAIRE

La définition du décalage horaire est la suivante : "syndrôme de retard temporel des pilotes d'avion". De nombreux symptômes cliniques apparaissent en raison de vols transméridiens rapides et répétés (1, 4, 8), tels que des perturbations du sommeil avec insomnie nocturne et somnolescence diurne, une réduction des performances physiques et cognitives, parfois des perturbations gastro-intestinales.Le personnel naviguant peut aussi présenter des effets chroniques du décalage horaire, comme des ulcères gastriques, des problèmes intestinaux, une fatigue chronique avec des insomnies et parfois une dépression nerveuse.

L'étiologie du décalage horaire est mal connue. Trois aspects sont impliqués : la fatigue du voyage (observée aussi dans les vols nord-sud), la lenteur et l'irrégularité d'adaptation du rythme endogène à la nouvelle heure locale (au moins la privation de sommeil) et la capacité à réagir à ces perturbations en particulier la récupération au cours du sommeil.

Les paramètres variant au cours du syndrôme de décalage horaire sont résumés dans le tableau suivant :

PARAMETRES INDIVIDUELS	***PARAMETRES ENVIRONNEMENTAUX***
-age	-direction du vol
-sexe	-bruits et température
-petit ou gros dormeur	-disputes
-"du matin" ou "du soir"	-literie
-facilité à dormir	-environnement psychologique
-privation de sommeil	

Tableau 1 : *Paramètres variant au cours du syndrôme de décalage horaire*

4• L'OPERATION PEGASE

Afin d'illustrer les effets du décalage horaire et particulièrement l'influence de l'âge, nous présentons les résultats d'une expérience en conditions réelles appelée "Opération Pégase".

Il s'agissait d'un exemple de déploiement de troupes qui induisait un décalage horaire et dans une moindre mesure une privation de sommeil. Cette situation provoquait de la fatigue et une baisse de la vigilance et des performances.

Il s'agissait d'une collaboration originale entre l'armée de l'air française, l'US Air Force, l'IMASSA (Institut de Médecine Aérospatiale du Service de Santé des Armées), l'Armstrong Laboratory et la société NESTLE. Cette expérience unique impliquait trois avions militaires (KC 135), 60 personnes étaient mobilisées. Un décalage horaire de 7 heures était provoqué par un vol transméridien vers l'Est entre San Antonio (Texas, USA) et Mont de Marsan (France), dans un contexte opérationnel, avec une population représentative (27 sujets sains, féminins et masculins, réservistes de l'US Air Force).

Au cours de cette expérimentation, nous avons évalué les vigilances subjective et objective, les performances physiques et cognitives, des taux hormonaux, et des paramètres physiologiques, soit au total 140 paramètres.

Ceux-ci étaient évalués au cours de deux périodes de tests, la première le matin (entre 09:00 et 12:00) et l'autre l'après-midi (entre 14:00 et 17:00), et étaient enregistrés avant le vol (période de référence de 2 jours) et après le vol (période de resynchronisation de 10 jours). Chaque période incluait la mesure de la latence d'endormissement (caractérise le niveau de fatigue), l'évaluation visuelle analogique (évaluation de l'état d'éveil, de la capacité de concentration, de l'anxiété et de la thymie), le renseignement des agendas de sommeil (aspects qualitatif et quantitatif du sommeil des sujets), la mesure de la fréquence critique de fusion lumineuse (étude de l'éveil du système nerveux central et évaluation du stress et de la fatigue des sujets), le test de barrage de signes (BATP) (mesure de la perfomance attentionnelle des sujets), les tests de la STRES Battery (évaluation des performances psychomotrices), le test de force de poigne, les tests de sauts (simple ou multiple) (étude des performances physiques) et un examen clinique. Les autres paramètres étaient mesurés à différents moments du jour et/ou de la nuit : prise de température buccale, actimétrie (suivi de l'activité en continu des sujets), évaluation visuelle analogique (pendant le vol), polysomnographie, prélèvements salivaires (cortisol, mélatonine, caféine).

Dans ce protocole, nous avons comparé trois situations : placebo versus mélatonine versus caféine à libération prolongée (une nouvelle forme galénique de caféine : STINERGIC®).

Dans ce papier, nous ne nous sommes intéressés qu'au groupe placebo (9 sujets, 3 femmes et 6 hommes de 20 à 46 ans – 3 de moins de 35 ans et 6 de plus de 36 ans).

Afin de présenter le protocole de cette expérience, un film de 15 minutes a été projeté au cours de la présentation orale.

5• PRINCIPAUX RESULTATS

Des test statistiques ont été réalisés en analysant les variances avec un facteur répété (l'âge) chez les jeunes et les vétérans (signification pour $p<0.05$). Dans le cas où une différence significative a été observée, un test de Newman-Keuls a été fait afin de classer ordinalement les résultats.

- Influence du décalage horaire (groupe entier)

Nous avons observé que 46 paramètres sur 140 ont été perturbés ou modifiés, ce qui représente 33%. Ces résultats démontrent l'effet globalement pénalisant du

décalage horaire sur une large population (27 femmes et hommes de 19 à 46 ans).
Nous voulons savoir si l'âge a induit des modifications supplémentaires sur les paramètres précédemment perturbés sans aide pharmacologique.

- Influence de l'âge (groupe placebo)

• Tests psychologiques

L'influence de l'âge était relativement limitée. Les résultats des échelles visuelles analogiques sont résumés dans le tableau suivant :

JOUR	CRITERE	VETERANS	JEUNES
J1	tous	NS	NS
J2	somnolent	- (p=0.018)	+ (p=0.018)
	idées claires	+ (p=0.004)	- (p=0.004)
	énergique	+ (p=0.006)	- (p=0.006)
	tranquille	+ (p=0.024)	- (p=0.024)
	vif d'esprit	+ (p=0.001)	- (p=0.001)
	rêveur	- (p=0.006)	+ (p=0.006)
	capable	+ (p=0.004)	- (p=0.004)
	amical	+ (p=0.014)	- (p=0.014)
	sociable	+ (p<0.001)	- (p<0.001)
	content	+ (p=0.044)	-(p=0.044)
	intéressé	NS	NS
	fort	NS	NS
	adroit	NS	NS
	relax	NS	NS
	heureux	NS	NS
	calme	NS	NS
J3	tous	NS	NS
J4	calme	+ (p=0.023)	- (p=0.023)
	relax	+ (p=0.044)	- (p=0.044)
	capable	+ (p=0.045)	- (p=0.045)
	autres	NS	NS
J5	rêveur	- (p=0.011)	+ (p=0.011)
	autres	NS	NS
J6	tous	NS	NS
J7	tous	NS	NS
J8	intéressé	- (p=0.039)	+ (p=0.039)
	autres	NS	NS
J9	tous	NS	NS
J10	tous	NS	NS

***Tableau 2** : Influence de l'âge dans les Echelles Visuelles Analogiques*

En résumé, au matin du deuxième jour, les vétérans se sentaient mieux que les sujets jeunes pour dix critères sur seize. Cela pourrait être dû à une meilleure qualité de sommeil chez les vétérans, comme cela a été démontré dans les agendas de sommeil la deuxième nuit ($p<0.01$), la huitième nuit ($p<0.05$) et la neuvième nuit ($p<0.05$) après le décalage horaire. Cette influence de l'âge a aussi été observée les quatrième et cinquième jours mais de façon limitée. Il est aussi intéressant de noter qu'au matin du huitième jour, les vétérans avaient une sensation d'ennui.
Il apparaît donc que l'âge a eu un effet positif sur la vivacité (le deuxième jour de la resynchronisation), sans que les autres critères n'aient été modifiés.
Le test C.F.F. a aussi montré une influence de l'âge. Les personnes jeunes avaient des fréquences de fusion plus élevées comparées aux vétérans les premier ($p=0.044$) et huitième ($p=0.015$) jours, mais seulement pour les sessions de l'après-midi, jamais celles du matin. Cela pourrait démontrer une légère baisse de vigilance chez les vétérans l'après-midi.

Les autres tests de vigilance (BATP, STRES Battery, MSLT) n'ont montré aucune influence de l'âge.

• Tests physiques

Les résultats des différents tests sont résumés dans le tableau suivant :

TEST	VETERANS	JEUNES
Test de Poigne	NS	NS
Test de Saut (simple et multiple)	NS	NS

***Tableau 3** : Influence de l'âge sur les tests physiques*

Aucune différence induite par l'âge n'a été observée sur les performances physiques.

• Tests hormonaux

Deux paramètres ont été mesurés dans les échantillons salivaires : la mélatonine et le cortisol. Les résultats sont résumés dans le tableau suivant :

HORMONE	VETERANS	JEUNES
Mélatonine	NS	NS
Cortisol	NS	NS

***Tableau 4** : Influence de l'âge sur les taux hormonaux*

Quelle que soit l'hormone mesurée, aucune influence significative de l'âge n'a été observée.

• Paramètres cliniques

Deux paramètres cardiovasculaires ont été mesurés : la presion artérielle et la fréquence cardiaque.
Pour la presion artérielle, aucun effet significatif de l'âge n'a été noté entre les vétérans et les jeunes. Cependant, il est intéressant de noter que le décalage horaire a induit une augmentation de la pression artérielle, mais qui reste comparable chez les vétérans et les jeunes.
En ce qui concerne la fréquence cardiaque, la fréquence cardiaque orthostatique était plus faible chez les vétérans les deuxième ($p=0.047$), troisième ($p=0.003$), quatrième ($p=0.007$), cinquième ($p=0.001$), sixième ($p=0.036$) et neuvième ($p=0.016$) jours. Aucune différence significative n'a été observée pour la fréquence cardiaque de repos.

6• DISCUSSION

Cette expérience montre qu'à la suite du décalage horaire, les vétérans se sentent moins perturbés que les jeunes et ont une meilleure qualité de sommeil (temps total de sommeil supérieur). En particulier, bien qu'aucune différence significative ne soit observée entre les jeunes et les vétérans en ce qui concerne la tranquilité et le bien-être, il existe un effet positif sur la vivacité.
Ces résultats peuvent peut-être être expliqués par le fait que la légère baisse des performances physiques des vétérans (due au décalage horaire) est compensée par leur expérience et leur entraînement qui leur permettent d'obtenir des résultats similaires aux jeunes.

De plus, il est intéressant de noter que le décalage horaire a globalement les mêmes effets cardiaques chez les jeunes et les vétérans. Cependant, chez les vétérans, la fréquence cardiaque orthostatique est parfois plus faible. Ceci pourrait confirmer qu'à la suite du décalage horaire, les vétérans sont moins stressés et ont une meilleure adaptation grâce à leur expérience.
Cette étude montre que l'influence de l'âge est plutôt limitée chez les vétérans, aussi bien aux niveaux physique que psychologique. Cela tend à démontrer que dans des conditions militaires opérationnelles, les vétérans auraient les mêmes performances que les jeunes.
Ces résultats auraient été différents et plus significatifs si le plus âgé des vétérans avait eu plus de 46 ans : des variations plus importantes ont été rapportées dans la littérature (7, 9, 13) où les sujets sont plus vieux que dans notre cas ; au cours de l'âge mûr et après, les performances physiques et cognitives sont plus perturbées.

7• RECOMMANDATIONS

Entre 20 et 45 ans et à fortiori après 45 ans, il est conseillé de prendre des contre-mesures pour limiter les effets du décalage horaire.
Dans le cas de situation opérationnelle, les recommandations sont les suivantes :
- rester éveiller après un vol transméridien afin de s'exposer à la lumière du jour, de participer aux activités sociales et de faire de l'exercice physique. Il est aussi possible d'améliorer l'efficacité de ces mesures ou de les remplacer par la prise d'une pilule de caféine à libération prolongée (STINERGIC®) (5, 11).
- pour faciliter la récupération de sommeil, il n'est pas conseillé de dormir pendant les 10 heures précèdant l'heure du coucher normal (en temps local), mais de prendre le soir, si les sujets peuvent disposer de 4 à 6 heures de repos (3), une pilule de zolpidem (STILNOX®, AMBIEN®,...) avant d'aller au lit – aussi confortable que possible (5).

En situation opérationnelle, il n'est pas nécessaire de prendre de la mélatonine comme substance hypnotique ou chronobiotique dans le cas où la bonne dose et le bon moment d'administration ne sont pas connus dans votre situation. Trop de café (solution de caféine), du fait de ses effets secondaires, n'est pas conseillé ; l'alcool est interdit (6).

8• CONCLUSION

En situation militaire, l'influence de l'âge sur le syndrôme de décalage horaire semble limité. Toutefois, il faut prêter attention à certains paramètres comme la fréquence cardiaque orthostatique ou ceux du sommeil. Des contre-mesures simples, sûres et efficaces existent afin de faciliter la récupération après un vol opérationnel transméridien.

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EVALUATION OF CREW MEMBERS AGING ON JET-LAG CONSEQUENCES.

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• ABSTRACT

Introduction : Travel across multiple time zones triggers a disruption of the body's circadian timing mechanisms of crew members and military force. It entails a desynchronization syndrome which depends on individual sensitivity. Weakness and sleep disorders are usually affected and cognitive (mood and attention) and physical (power and endurance) performances can be decreased.

The purpose of this study is to evaluate a possible effect of age on individual sensitivity for a jet-lag.

Methods : The study, which evaluates the influence of age, belongs to a large franco-american study (Pegasus Operation) in which circadian rhythms of resynchronisation and effects of jet-lag on operational performances were observed.

Nine subjects were submitted to an eastbound transatlantic air travel across seven time zones in operational military condition and without pharmacological aids.

The influence of age was evaluated on vigilance and mood tests (visual analog scale, sleep log, Critical Flicker Fusion Frequency), and alertness test (sign cancelation) and physical performances tests (hand grip strength and vertical jumps). Each test was realized twice a day (morning and afternoon) for ten days after the travel.

Results : Subjects (aged 37 ± 8,2 years) were distributed in two groups : less than 35 and more than 35.

There was no significant effect of age on physical performances and alertness tests.

The influence of age on Critical Flicker Fusion Frequency test was very limited (it evaluated the cognitive awakening of central nervous system).

According to sleep log test, another test for vigilance, young people had a subjective quality of sleeping lower than veterans, during the second, eighth and ninth nights after jet-lag. The influence of age was only significant from the second to the fifth day : morning of the second day, veterans felt better than young subjects, in ten criteria on sixteen for visual analog scale. This feeling was present the forth and fifth day but in a limited way. Veterans were bored at morning of the eighth day.

About cardiac parameters, orthostatic heart rate is sometimes lower for veterans than youngs.

Conclusion : The influence of age seems to be weak on subjects vigilance. Age has an important impact on personal evaluation of mood, especially marked the second and fifth days but without discrimination on physical and cognitive performances.

Thus, this experimentation, realized in operational military conditions, does not confirm review data. Veterans, maybe because of their experience, are not affected by jet-lag in our study conditions.

1• INTRODUCTION

During long-haul flights, civilian and also military pilots suffer from jet-lag syndrome. Symptoms are different during military flights, for example during a troops deployment, because of stress and lack of comfort.

Before studying effects of this particular type of jet-lag and evaluating its consequences with aging ,and because of the relationship between vigilance and sleep, we would like to begin with a summary of age physiological modifications of sleep. We will continue with an example of jet-lag syndrome in a military situation, and conclude with few recommendations.

2• PHYSIOLOGICAL MODIFICATIONS DUE TO AGING

Main deteriorations which occur from 35 are a decrease in circadian rhythms amplitude, a phase advance and a period shortening of temperature, melatonin and light/dark cycle rhythms, an increase in sleep onset latencies and stages 1 and 2, a decrease in Slow Wave Sleep (stages 3 and 4) and REM as a sleep fragmentation (increase in Wake After Sleep Onset) (2, 10, 12). These phenomena could be mainly explained by reduction of retina sensivity to light and by morphological and chemical changes of suprachiasmatic nuclei and epiphysis (decrease in melatonin secretion). The resulting altered quality of sleep, affects performances and mood of subjects. A detailled study of sleep modifications due to aging will be presented in a next presentation of this symposium.

3• JET-LAG SYNDROME

The signification of jet-lag is : "Jet engine airliner time lag syndrome". Many clinical symptoms appear, because of rapid and repeated transmeridian flights (1, 4, 8), such as sleep disturbancies with nocturnal insomnia and

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diurnal drowsiness, reduction of physical and cognitive performances and sometimes digestive disturbancies.
The flying personnel could present chronic effects of jet-lag too, such as gastric ulcers, intestinal disorders, chronic fatigue with insomnia and sometimes a nervous breakdown.
The jet-lag etiology is not well known.Three aspects are concerned : the fatigue due to travel (seen also in north-south flights), the slowness and irregularity to adjust endogenous rhythm to new local hour (at least the sleep deprivation) and the capacity to react to this troubles by sleep recovery.
The variability parameters of the jet-lag syndrome are summarised in the following table :

INDIVIDUAL PARAMETERS	*ENVIRONMENTAL PARAMETERS*
-age -gender -big and small sleepers -morningness and eveningness type -sensitivity to sleep deprivation	-flight direction -noise and temperature levels -conflict intensity -bedding -psychological environment

Table 1 : *Variability parameters of the jet-lag syndrome*

4• PEGASUS OPERATION

To illustrate effects of jet-lag and especially the influence of age, we present some results from a real world experiment called "PEGASUS OPERATION".
It is an exemple of troops deployment which induces jet-lag and limited sleep deprivation. This situation provokes fatigue and a decrease of vigilance and performance.
It was an original collaboration between french Air Force, US Air Force, IMASSA (Institut de Médecine Aérospatiale), Armstrong Laboratory and NESTLE Company.
This unique experiment included 3 military planes (KC 135), 60 people were involved. A jet-lag of 7 hours was due to a transmeridian flight between San Antonio (USA) and Mont de Marsan (France), in an operational setting with a representative population (27 healthy subjects, males and females, reservists from US Air Force).
During this experiment we evaluated the subjective and objective vigilance, the physical and cognitive performances, hormonal proportions, and some physiological parameters, *i.e.* 140 parameters.
These parameters were evaluated during two periods of tests, one on mornings (between 09:00 and 12:00) and another one on afternoons (between 14:00 and 17:00) and were recorded before the flight (reference period during 2 days) and after the flight (recovery period during 10 days).
Each period included : Measure of Sleep Latency Test, Visual Analogue Scales, Sleep Log, Critical Flicker Fusion Test, BATP Attention Test, STRES battery, Grip Test, Jump Test and a clinical examination. Other parameters were evaluated at different moments of the day or the night : temperature, actimetry, Visual Analogue Scales (during the flight), EEG, salivary samples (cortisol, melatonin, caffeine).

In this protocol, we compared three situations : placebo versus melatonin versus slow release caffeine (a new galenic form of caffeine : STINERGIC®).
In this paper we interest only in placebo group (9 subjects, 3 women and 6 men ranged from 20 to 46 - 3 less than 35 and 6 more than 36).
To present the methodology of this experiment, a movie of 15 minutes duration was shown during the oral presentation.

5• MAIN RESULTS

Statistical significance was determined by variance analysis with one repeated factor (age) for youngers and veterans ($p<0.05$). In case of significative difference, a Newman-Keuls test was made in order to ordinaly classify results.

- Influence of jet-lag

We observed that 46 parameters on 140 were disturbed or modified *i.e.* 33%. These data demonstrate the global penalizing effects of jet-lag on a very large population (men, women from 19 to 46 years old).
We would like to know if aging induced additional modifications on parameters previously disturbed.

- Influence of age

• Psychological tests

The influence of age is very limited. Results of the Visual Analogue Scales are summarized in the following table :

DAY	*CRITERION*	*VETERANS*	*YOUNGERS*
D1	all	NS	NS
D2	drowsy	- (p=0.018)	+ (p=0.018)
	clear-headed	+ (p=0.004)	- (p=0.004)
	energetic	+ (p=0.006)	- (p=0.006)
	tranquil	+ (p=0.024)	- (p=0.024)
	quick-witted	+ (p=0.001)	- (p=0.001)
	dreamy	- (p=0.006)	+ (p=0.006)
	proficient	+ (p=0.004)	- (p=0.004)
	amicable	+ (p=0.014)	- (p=0.014)
	gregarious	+ (p<0.001)	- (p<0.001)
	contented	+(p=0.044)	-(p=0.044)
	interested	NS	NS
	strong	NS	NS
	well-coordinated	NS	NS
	relaxed	NS	NS
	happy	NS	NS
	calm	NS	NS
D3	all	NS	NS
D4	calm	+ (p=0.023)	- (p=0.023)
	relaxed	+ (p=0.044)	- (p=0.044)
	proficient	+ (p=0.045)	- (p=0.045)
	others	NS	NS
D5	dreamy	- (p=0.011)	+ (p=0.011)
	others	NS	NS
D6	all	NS	NS
D7	all	NS	NS
D8	interested	- (p=0.039)	+ (p=0.039)
	others	NS	NS
D9	all	NS	NS
D10	all	NS	NS

Table 2 : *Influence of age in Visual Analogue Scales*

In summary, on morning of the second day, veterans felt better than young subjects in ten criteria on sixteen. This could be due to a best sleep quality for veterans, as demonstrated in the Sleep Log test the second night ($p<0.01$), the eighth night ($p<0.05$) and the ninth night ($p<0.05$) after jet lag. This influence of age was also observed the fourth and fifth days, but in a limited way. It is also interesting to notice that on morning of the eighth day, veterans had a feeling of boredom.
So it appears that the age had a positive effect on vivacity (the second day of resynchronization), other criteria were not modified.

The C.F.F. test also showed an influence of age. Young people had higher fusion frequencies than veterans the first day ($p=0.044$) and the eighth day ($p=0.015$), only on afternoon sessions, never on mornings. This should demonstrate a small decrease in veterans vigilance on afternoon.

According to other alertness tests, no significant effect of age was observed (BATP, STRES Battery, MSLT).

• Physical tests
Results from the different tests are summarized in the following table :

TEST	*VETERANS*	*YOUNGERS*
Grip Test	NS	NS
Jump Test (squat and multiple)	NS	NS

Table 3 : Influence of age in physical tests

Any difference due to age was observed in physical performance.

• Hormonal tests
Two parameters were evaluated in salivary samples : melatonin and cortisol. Results are summarized in the following table :

HORMON	*VETERANS*	*YOUNGERS*
Melatonin	NS	NS
Cortisol	NS	NS

Table 4 : Influence of age in hormonal measurements

Whatever the hormon tested, no significant influence of age was observed.

• Clinical parameters
Two main cardiovascular parameters were evaluated : blood pressure and heart rate.
Concerning the blood pressure, no significant effect of age was observed between veterans and youngers. However, it is interesting to notice that jet-lag induced an increase in blood pressure comparable for veterans and young people.
About heart rate measurements, orthostatic heart rate was lower for veterans the second day ($p=0.047$), the third day ($p=0.003$), the fourth day ($p=0.007$), the fifth day ($p=0.01$), the sixth day ($p=0.036$) and the ninth day ($p=0.016$). No significant difference was observed for decubitus heart rate.

6• DISCUSSION
This experimentation shows that after jet-lag, veterans feel better than young people and have a best sleep quality (total sleep time is longer).In particularly, no significant difference between youngs and veterans was pointed out on the quietude and the well-being, and a positive effect was observed on vivacity.
These results can be explained by the fact that the little decrease in veterans physical performance (due to jet-lag) is balanced by their experience and training which allow them to get similar results as youngers.
Moreover, it is interesting to notice that jet-lag has globally the same cardiac effects for youngers and veterans. However, for veterans, the orthostatic heart rate is sometimes lower. This could confirm that after jet-lag, veterans are less stressed and have a best adaptation because of their experience.
This study shows that the influence of age is very limited for veterans, as well on physical as psychological approach. It tends to demonstrate that in operational military conditions, veterans would have the same performances than youngers.
These results would be more different if the older veteran would have more than 46. More variations are found in the litterature (7, 9, 13) in which subjects are generally older than in our situation ; in middle age and elderly, physical and cognitive performances are disturbed.

7• RECOMMENDATIONS
Between 20 and 45 years old and more obviously after 45 years old, it is advised to take some counter-measures to beat jet-lag.
In the case of an operational situation, recommendations are :
- to stay awake after a transmeridian flight is recommended to expose himself to day light, to participate to social activities and to do physical exercise. It is possible also to major the efficiency of these measures or to replace them, by taking a pill of slow release caffeine (STINERGIC®) (5, 11).
- to facilitate sleep recovery, it is not recommended to sleep during the 10 hours preceding time to go to bed (in local time), but taking a pill of zolpidem (STILNOX®, AMBIEN®,...) just before going to a good bed - as confortable as possible - is recommended (5) if the subjects have 4 to 6 hours free to rest(3).

But in an operational setting, we do not recommand taking melatonin as an hypnotic or a chronobiotic substance, if the right dose and the right time of administration are not well known. Too much coffee (caffeine solution), because of its side effects, is not recommended ; alcohol is prohibited (6).

8• CONCLUSION

In military condition the influence of age in jet-lag syndrome seems to be limited. Nevertheless, some parameters need attention : the orthostatic heart rate or the modified sleep parameters. Some easy and safe countermeasures exist to facilitate recovery after an operationnal transmeridian flight.

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AGE DEPENDENT ALTERATIONS INDUCED BY TRANSMERIDIAN FLIGHTS IN AIRLINE PILOTS

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Running head: Changes in transmeridian flights

Abstract.

Desynchronization among body rhythms and with the environment appears to be linked with *jet lag*, which may depend on many factors, including age, flight direction and number of time-zones crossed. To analyze this chronobiological state, we performed a multivariate analysis of the circadian system of airline pilots younger and older than 50 years, in Madrid-México-Madrid (-7 time zones, n=12) and Madrid-Tokyo-Madrid (+8 time zones, n=21) flights. Telemetrical devices were used to record pilots' locomotor activity, skin temperature and heart rate, during the flights to and from destiny, and one day after returning to Madrid.In addition the excretion of 6 sulphatoxy melatonin and free cortisol was measured in 6 hourly intervals during the whole period.. Time series were analised by cosinor and the rhythms were compared by ANOVA and Tukey contrasts. Age (under and over 50 years old) and flight direction groups were considered. Different psychometric tests were carried out at different times of the fligths in order to know how pilots are affected by transmeridian flights. Subjective time estimation was also recorded, as well as other psychological variables including anxiety, tiredness and performance. Activity / rest and heart rate rhythms are easily adapted to the new time zones whereas temperature rhythms manifest a rigid response after the phase shifts. Subjective time tended to be overestimated without exhibiting a clear circadian component. Psychometric evaluation showed that desinchronization affects all the pilots. Some results show an age-related variability with more marked influence in younger pilots, while no consistent effects of the flight direction were found.

Keywords: Jet lag; circadian rhythms; airline pilots; temperature; locomotor activity; heart rate, anxiety, tiredness, performance

Introduction

Biological rhythms are the result of two interacting components: an endogenous one called biological clock and an exogenous, time-giver component or a *zeitgeber* (2,16) that is determined by the Geophysical variables. The synchrony between these components is the obvious adaptative value of the rhythms (13, 55, 60).

Circadian rhythms (i.e., with periods of about 24 h) disorders are focused especially on the alterations of entrainment pathways, that can be related to internal causes or with ageing and blindness (12). Exogenous alterations are caused by a mismatch between the body circadian rhythms and the environmental *zeitgebers* (13, 29, 31) as for example during Jet lag in which time-zone travellers encounter a pattern of light and darkness, activity, and social schedules shifted in time. The endogenous circadian system is slow to adapt to new time cues raising physiological and behavioral problems that are manifest until the correct phase relationship between biological rhythms and external *zeitgebers* is established. (15, 19).

After time-zone transitions, body rhythms become out of phase with the light/dark *zeitgeber*, and a new steady state is reached after reactive and predictive homeostatic mechanisms (3). Therefore they will be out of phase with each other during the process producing a temporal internal disorder or internal desynchronization, which is responsible for the general malaise, disturbed sleep, loss of mental efficiency, anxiety, irritability, tiredness and gastric disorders which are commonly reported in the first week or so after a long haul flight (20, 24, 31). These symptoms seem to increase with the number of time zones crossed (9,25) and age. There are not many studies concerning the population most at risk of being affected by transmeridian long-haul flights, i.e., the airline pilots although these alterations might have important effects in them. Here we present the results of a 2 yr. field study of Spanish pilots flying the routes from Madrid (Spain) to Mexico City (Mexico) or from Madrid to Tokyo (Japan). A number of physiological (locomotor activity, temperature, heart rate,hormonal excretion) and psychological (anxiety, tiredness, performance, etc.) variables were simultaneously recorded throughout the

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whole flight schedule taking into consideration the age of the individuals. Subjective time estimation recordings, were also performed as well as measurements of the urinary excretion of melatonin and free cortisol

Methods.

Subjects
Volunteers were male pilots of IBERIA airlines involved in transmeridian westward flights of the route Madrid-México-Madrid, (-7 time zones between Madrid and México, n=12). They were divided in two age groups: <50-yearold (n=5, average age 38.6±5.7 SD, range 31 to 47 yr), and >50- year old (n=7, average age 58.0 ± 1.0 SD, range 57 to 59 yr). The eastward flights were Madrid-Tokyo-Madrid, (+8 time zones, n= 21), and the groups of age were <50 years (n= 11, average age 38.7 ±2.1, range 35 to 42 yr), and> 50 (n= 10, average age 55.1 ± 2.2 SD, range 53 to 58 yr).

Recordings
Six days of continuous telemetrical recording were completed: the two days before the flight in Madrid were considered as baseline values (MAD1). The two days at the layover (MEX or TOK) were taken as "destiny" recordings, and the returning flight and the day after it in Madrid (MAD2) was used as the "post-flight" parameter. Recordings were performed with the Mini-Logger® series 2000 system (Minimitter Co., Inc., Sunriver, OR). Locomotor activity sensors were piezoelectric cristals of mercury located in a wristlet. Skin temperature recordings were performed to estimate core temperature because chronical rectal probes were inadequate in this experimental situation at the actual work site of the subjects. Callibrated sensors were located in chest belts to register heart rate.

Psychological tests

In order to evaluate pilots'anxiety and fatigue, we used: the S.T.A.I. (State-Trait Anxiety Inventory) of Spielberg (23) adapted to the Spanish population by Seisdedos Cubero (1994). The last part of this test (anxiety trait) was scored only once before the departure flight. A part of this instrument (question 8) was used as a reference of the changes in fatigue levels. In order to evaluate the alertness and perceptive state of the pilots, we used the Identical Figure test (Thurstone 1986) (27).. and the Perceptive-Spacial test (Seisdedos Cubero 1990) (22). All these measurements were carried out just at the beginning of the study in Madrid, before and at the end of the flights (**forward and return**), during the stopover days, and finally 24h after returning to Madrid. Non flying persons remaining in Madrid (n=10) served as controls.

Urine samples

Urine samples were collected in 6 hour periods (00:00-06:00, 06:00:12:00, 12:00-18:00,and 18:0024:00)over the six days of the study. The volume of each sample was measured and recorded andaliquots were kept on dry ice until analysis. The excretion of 6- sulfatoxymelatonin and cortisol in each sample was measured by RIA using commercial kits (6-sulfatoxymelatonin kit,Stockgrand,Surrey UK; cortisol kit Incstar Co ,Minnesota,USA) All samples were measured in the same RIA to avoid interassay variation.

Analysis
The sampling interval was of 5 minutes in every measured variable. The original cosinor time series was studied by serial cosinor analysis. Analysis of variance (ANOVA) with one fixed factor and Tukey's tests were used to compare the circadian parameters. Acrophase (defined as the time when the maxima of variables occurred) maps were constructed for locomotor activity and temperature, plotting the acrophase value of both rhythms for the five days versus Madrid clocktime.

Time estimation
Time estimation assessment was performed with special software. This program offers a set of different durations of auditive stimuli, which the subject has to estimate and/or reproduce .The computer analyzed and characterized the different ratios between real and estimated values.

Psychological variables

To evaluate the modification of the psychological tasks two non-parametric tests (Mann-Whitney for non related samples, and Wilcoxon for related samples) were used.

Results.

Activity/rest rhythms.
Locomotor activity showed a clear 24-hour rhythm at baseline It exhibited a rapid phase shift at destinations both after México and Tokyo flights by a 7 hour-delay and an 8 hour-advance respectively, following the phase shift of the light/dark *zeitgeber*. In all cases, a Madrid-like acrophase was reestablished after the return flights to Madrid. Disrupted activity/rest rhythms were observed during the stopover with activity events occuring during the night as well as a significant decrement of the amplitude in both age groups after flights to Tokyo .No significant differences were detected among age groups.

Temperature rhythms.
Skin temperature recordings show a clear circadian rhythmicity, despite the large interindividual variations.

Acrophases were not clearly affected by the initial flight to either Tokyo or Mexico remaining at times corresponding to normal conditions in Spain. Amplitude decremented significantly after the flights to México in the older group

Heart rate rhythms.
Circadian-like rhythms could be observed in the age recordings average fluctuating around the normal range of physiological values. Acrophases were clearly phase shifted only in younger pilots after the flights to Mexico and Tokyo,together with a decrease in amplitude that was also evidenced in the Tokyo flight. No significant changes occur in those over 50 years of age.

Time estimation
A significant overestimation of time was observed at destination in each cathegory, independently of flight direction. The S/R ratio was reverted after returning from México, not after Tokyo flights, with overestimation persisting for at least 2 more days.

Urinary hormonal excretion

Data about the urinary excretion of 6 sulphatoxy melatonin have been previously reported (27 bis).Pilots flying both to Mexico an Tokyo showed a pattern of free cortisol excretion that was similar to that found in the control group,although with strong interindividual variations. Pilots older than 50 years of age exhibited lower excretory values than the younger ones (p<o.o2)

Psychological Variables

Anxiety levels were low in absolute terms, in all the pilots. However, younger pilots showed relatively higher levels of anxiety with respect to basal levels in several of the periods monitored. Surprisingly, we found that older and younger pilots had increased significantly(p<o.o5) the anxiety levels during the second stopover day, especially the younger group (10% older – 40% younger). This profile was not found in eastward flights In contrast, the pilots under 50 mantained high levels of anxiety during the first stopover day and had a decrease during the second stopover day. Returning from Tokyo, the younger pilots had a anxiety peak at the end of the return flight and this score was the highest_studied (16.8 $\pm$ 7.8) and very significant ($p<0.01$) in comparison with the basal levels. Again, most of the pilots of this subgroup were young.

The pilots showed two peaks of tiredness at the end of every flight, both in west and in eastbound flights During westward flights pilots showed an earlier recovery than in eastward flights. A difference between old and young pilots existed in eastbound flights, the latter showing significantly higher levels of tiredness ($p< 0.05$).

Older pilots showed less improvement in the execution of attentional-perceptive_tasks than controls or younger pilots as demonstrated in the Identical Figure Test and in the Spacial Test

Discussion

Time zone transitions imposed by rapid long haul transmeridian flights present the possibility of studing the human circadian system. (4, 16). After phase shifts of the light/dark cycle induced by the flights, core temperature rhythm manifests a slow rate of entrainment, while heart rate and activity/rest rhythms are entrained faster due to their plastic phase responses.
Skin temperature variations may represent a good estimator of the core temperature rhythm (29) and can be measured as physiological correlates of performance, alertness/fatigue, and the sleep/wake rhythm (7). When temperature rises, alertness is maximal. In contrast , when the body temperature values begin to decrease, falling asleep is easier. Therefore, performance decrements during reentrainment of the body rhythms (7, 20, 31) are associated with a non-consolidate night sleep (25)
Heart rate rhythmicity exhibits a large interindividual variation (5,7,11).
Locomotor activity, might be influenced by the motivational state of the pilots and the social *zeitgeber* at the different destinations.
Skin temperature rhythms, show a rigid phase response to light/dark cycle phase shifts, probably related to core temperature (29). Disturbed nocturnal sleep during the stopover, was associated with a desynchronization between temperature and activity/rest rhythms.
With aging, adaptation to time zone transitions appears to be more difficult (10, 14, 17, 26). Tolerance to jet lag is evaluated by means of the magnitude of amplitude (10,14,17). In our study, we found that activity and heart rate rhythms of the under 50-yr old group remained coupled during reentrainment, which didn't occur in older age group. The abnormal position of temperature acrophases in the over 50-yr old group could be attributed to the weak expression of elderly temperature rhythms.
Although large shifts in urinary cortisol levels could be overseen by employing 6 h sampling intervals the data suggest that the pattern remains bound to Madrid time during all the period,thus being out of phase with the external environment.Harma et al (10 bis) reported a 6 hour delay within 4 days after westward flights in a group of flight attendants .
Subjective time estimation did not exhibit circadian-like responses after the temporal alteration.. Therefore, the

relative failure in temporal estimation could be attributed to fatigue and stress caused by long haul flights.

It is generally accepted that delays of light/dark cycle (i.e., after westward journeys) produces less jet lag symptoms than advances (eastward journeys) (13, 4). In our case, we did not find any marked effect of flight direction on the circadian parameters being analysed. More precise measures of oscilator outputs (i.e., utilizing rectal probes for temperature) should be used in order to remove exogenous influences (13), a consideration that exceeds the objectives of the present study.

The findings in the present investigation suggest that an active reentrainment process start during the stopover, and may require several days in order to be completed. If a long rest strategy is choosen, aircrew would be exposed systematically to a reentrainment process, while a short stopover time, although less threatening to the body clock, probably would not allow pilots to have the necessary rest and alertness for the returning flight

Psychological alterations were always very moderate. Anxiety was low in all the pilots. This finding is not surprising, since pilots are trained to face emergency situations. Younger pilots exhibited the highest anxiety levels in both flight directions. In eastbound flights levels of anxiety are associated with high levels of tiredness after the return flight. Also in eastbound flights, anxiety level was higher than in westbound flights and more pilots repeated high scores in different evaluations.

Anxiety levels increased in the second stopover day in westbound flights, especially in young pilots, coinciding with increased tiredness and decreased performance. Nicholson (18) found similar results in these directional trips. As expected, tiredness was maximum at the end of the trip to destination and return flights, but it was highest in the eastward flights and in pilots under_50, associated to the more marked levels of anxiety.

Performance increased in all the subjects due to the learning process linked to the repetitive execution of the same test. Non flying controls always obtained the highest scores in the Identical Figure test, followed very closely by younger pilots, whereas pilots over 50 yr. got the lowest suggesting that the biological circadian rythm of the older pilots remains in close synchronyzation with Madrid. This also justifies the poorer results obtained during the flights and the recovery after resting in Madrid.

Our results suggest that commercial pilots have adequate adaptation strategy to afront westbound flights of long duration. The return flight has the additional problem of a long night to which pilots have only parcially adaptated. In contrast, eastbound flights, cause a clear disruption of all studied variables.

Alternative strategies for improving jet-lag symptoms are currently under experimentation, including the pharmacological use of chronobiotics (agents which modify clock activity) (1, 9, 18) or the stimulation of the circadian system with bright lights at specific times of the cycle (6, 8, 21, 30).

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Influence of Age on Alertness and Performance during 3-day cross North-Atlantic Operations

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SUMMARY

From literature it is known that a relationship exists between age and pilot's performance. Furthermore age correlates with shorter sleep, impaired sleep quality, difficulty in adapting to irregular work schedules and rapid time zone transitions. These factors may aggravate the effect of age and lead to impaired performance during flight duties.
Data from North-Atlantic operations (59 pilots) were used to investigate the relationship between age and alertness and performance during long haul operations. Pilots were equipped with a palm top computer and an actigraph for subjective and objective measurement of quantity and quality of sleep, alertness, and performance on a vigilance dual-task.
During the entire operation, no differences were found on subjective alertness between the younger and older pilots. Vigilance and tracking performance profiles appeared to be similar for both groups. Vigilance performance of older pilots was better after waking up and during the inbound leg. However, tracking performance of this group was worse before bedtime at stopovers and during the inbound leg. Performance was significantly correlated with age, but when correcting for baseline performance (home base), significancy almost disappeared.
It was concluded that, although performance of older pilots impaired more during the outbound flight as compared to younger pilots, sleep quantity and quality during the stopover night were sufficient to made them recover, and to perform at an adequate level on the return flight.

INTRODUCTION

The cognitive functions generally assumed to be important to the proper performance of in-flight tasks (1,2,3,4,5) are:

- perception (e.g. instrument monitoring)
- memory (e.g. remembering information given by air traffic control)
- problem-solving and decision-making (e.g. diagnosis of faults and defects)
- psychomotor coordination (e.g. flight control).

It is also assumed that more general cognitive functions, such as attention, concentration, and information processing speed, become more important with increasing age.
Furthermore, it is known that aging correlates with shorter sleep, impaired sleep quality, difficulty in adapting to irregular work schedules and rapid time zone transitions (6,7,8). These effects may aggravate the effects of age on pilot's performance and lead to impaired performance during flight duties (9,10,11).
For the most part, data on the effects of ageing on cognitive functions are obtained from studies in which the research population consisted of non-pilots (12,13,14). Only a limited quantity of literature is available on pilots. Since pilots are selected for these above-mentioned faculties, it is not right to generalise on the basis of data obtained from non-pilot populations.
As data from an earlier study on the effects of a controlled in-flight rest on North-Atlantic operations (15) were available, these data were used to investigate the relationship between age, alertness and performance, and to analyse the possible co-related effects of sleep during the trip.

METHOD

Subjects

The study included 59 pilots (30 captains and 29 first officers) flying on Boeing 747-300 operations, who were executing regular trips within their regular duty roster. Subjects were divided into two age groups; the younger pilots (n=34, mean 32.1, range 23-39 years) and the older pilots (n=25, mean 46.4, range 40-57 years). Mean total flight hours for the young group was 4955 (range 2.000-9.200) and for the older group 11.640 (7.000-17.000).

Trip characteristics

Measurements were made on 3-days North Atlantic trips involving Boeing 747-300 operations with a 3-person cockpit crew (Cpt, FO, FE). All outbound flights were executed during daylight and all inbound flights during the night. Stopovers included a time period of 22-25 hours from the afternoon on the day of arrival till the afternoon or evening the next day.

Assessment methods

Specific measures were chosen to evaluate sleep, alertness, and performance. Pilots were equipped with a Psion-3a palmtop computer to log subjectively estimated duration of sleep, sleep latency, total sleep time. Objective sleep data was recorded using an actigraph device. Using the event button, subjects marked beginning and end of sleep periods. In addition, the quality of sleep during the pre-trip night (at home) and the stopover night was assessed (16).
The Stanford Sleepiness Scale (17) was used to assess subjective alertness throughout the trip (Table 1). This subjective rating scale has proven to be sensitive in detecting any significant increase in sleepiness or fatigue.

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Furthermore SSS measures showed to be highly correlated with flying performance and threshold of information processing speed during periods of intense fatigue (18).

Table 1: Stanford Sleepiness Scale (SSS)

1. Feeling active and vital; alert; wide awake
2. Functioning at a high level, but not at peak; able to concentrate
3. Relaxed; awake; not at full alertness; responsive
4. A little foggy; not at peak; let down
5. Foggy; beginning to lose interest in remaining awake; slowed dow.
6. Sleepy; prefer to be lying down; fighting sleep; woozy
7. Almost in reverie; sleep onset soon; losing struggle to remain awake

The performance task used in this study (VigTrack; Fig.1) was a dual-task, which measures vigilance performance under the continuous load of a compensatory tracking task (19). This task was successfully applied in studies on the effects of irregular early reporting times on alertness of pilots in short-haul operations (20), sedative effects of antihistamines, and alcohol (21,22). The VigTrack probes two important aspects of the behavioural capability of aircrew, and is not a measure of overall operational performance. However, high levels of performance on the VigTrack require sustained attention for 5 minutes, while attention is distracted by the tracking task. To the extent that attention and adequate tracking are critical features of many tasks involved in the safe operation of aircraft, the VigTrack data provide information about operational readiness and vigilance.

Fig. 1. Psion 3a: Vigilance and Tracking task (VigTrack)

Procedure and experimental design

A schematic overview of the procedure is presented in Table 2. Before the trip, pilots were instructed how to use the actigraph and the Psion-3a palmtop computer. They were trained on the performance task and briefed on the subjective rating procedures. Each pilot was equipped with his own actigraph and Psion-3a. During the outbound flight, test sessions were performed just before and circa ¼ hour after the cockpit rest, and half an hour before top of descent. All sessions included SSS and VigTrack. The test procedure during the inbound flight was identical to the procedure applied on outbound flights. After their return at Amsterdam, actigraph and Psion-3a were collected and data were downloaded in a database.

Table 2: Test procedure: GSQS: Groningen Sleep Quality Scale; SSS: Stanford Sleepiness Scale; VigTrack: vigilance and tracking task.

Before Trip	instruction and training on task
Pre-flight	sleep data / GSQS / SSS / VigTrack
Outbound	
Pre-Rest	flight data / SSS / VigTrack
Post-Rest	SSS / VigTrack
Top of Descent	SSS / VigTrack
Stopover	
Before sleep	SSS / VigTrack
After Sleep	sleep data / GSQS / SSS / VigTrack
Inbound	
Pre-Rest	flight data / SSS / VigTrack
Post-Rest	SSS / VigTrack
Top of Descent	SSS / VigTrack

RESULTS

Age and alertness

No relationship was found between age and subjective alertness. During the entire trip, alertness profiles were comparable for younger and older pilots (Fig. 2). On average, both groups rated themselves as 'functioning at a high level' (score = 2) and 'relaxed awake' (score = 3) before and during the outbound leg. Before going to bed at the stopover hotel, they felt 'slowed down' (score = 5) and 'sleepy' (score = 6). The next day, they were not fully recovered, as compared to home base, but remained 'relaxed' and 'responsive' throughout the inbound leg (score = 3).

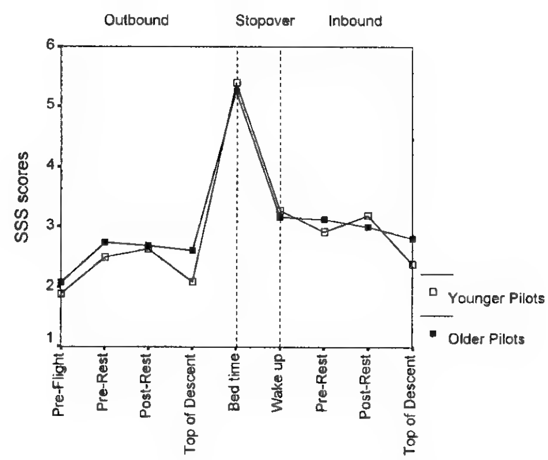

Fig. 2. Mean alertness scores (SSS) for younger and older pilots during the entire trip.

Age and performance

Performance profiles for the vigilance component (% omissions) of the VigTrack task appeared to be similar for the two groups (Fig. 3). Overall, younger pilots performed significantly better on the vigilance task than older pilots ($F(1,488) = 60.97$, $p<.001$). However, this difference disappeared when correcting for baseline (pre-flight) values. Analysing these differences scores, younger pilots showed a greater, but not significant, deterioration during the trip than older pilots; they performed better during the outbound trip but worse during the return flight.

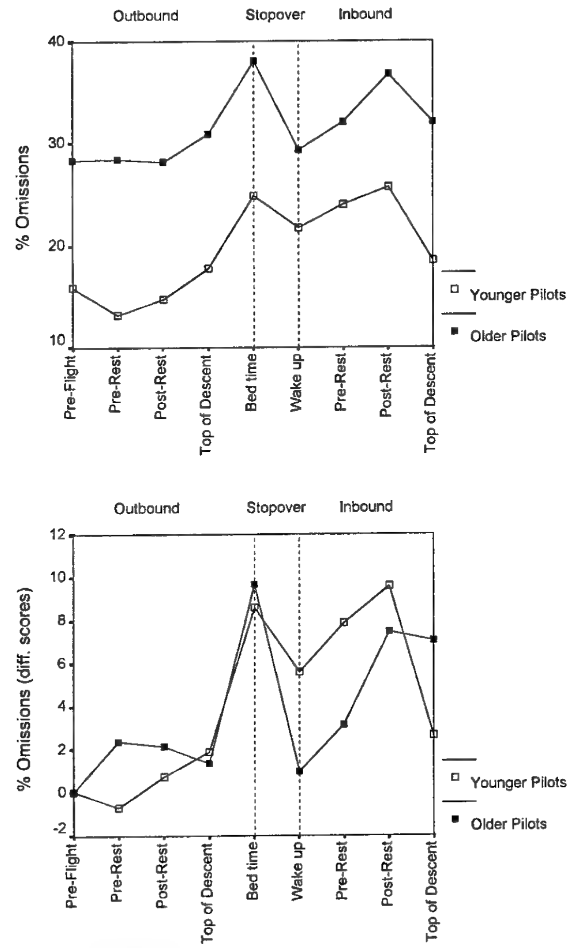

Fig. 3. Mean vigilance scores (% omissions): absolute scores (upper panel) and difference scores (lower panel) for younger and older pilots during the entire trip.

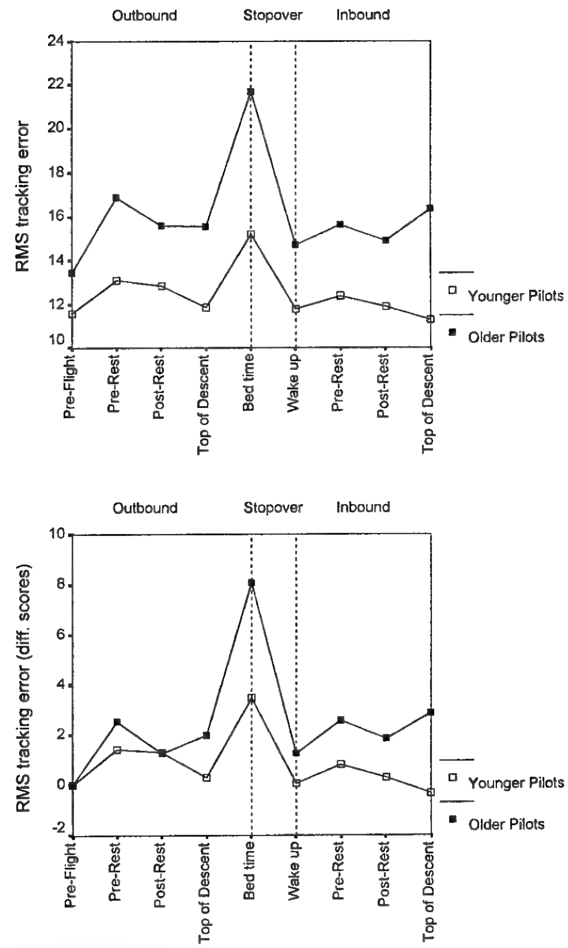

Fig. 4. Mean tracking scores (RMS): absolute scores (upper panel) and difference scores (lower panel) for younger and older pilots during the entire trip.

Performance profiles for the tracking component (RMS) of the VigTrack task were similar for both groups (Fig. 4). Overall, older pilots performed significantly worse ($F(1,488) = 42.28$, $p<.001$), also after correcting for baseline values ($F(1,488) = 13.91$, $p<.001$). This difference was most significant during the inbound leg ($F(1,219) = 8.81$, $p<.003$). Tracking performance (difference scores) of older pilots tended to deteriorate from the stopover night until top of descent of the return flight, while younger pilots remained at baseline level ($t = -1.89$, $p < .065$ resp. $t = -1.71$, $p < .094$).

The correlation between vigilance and tracking performance and age was computed using regression techniques. In table 3 regression coefficients and regression equations are given. Although a significant linear relationship was found between age and vigilance performance, the linear model explained only 9% of the variance. Tracking performance was clearly affected by age, and the scores presented in Fig. 5 (upper panel) suggested that age-related changes might contain a curvilinear component.

Regression analyses indicated that a curvilinear (cubic) model explained significantly more age-related variance (33%) than did a linear model (29%). Using both parameters (% omissions and RMS tracking error), standardized predicted values were calculated and overall performance was fitted in relation to age (Fig. 5, lower panel). Here too, a cubic model explained significantly more age-related variance (40%) than did the linear model (37%). Furthermore, this composite score explained significantly more variance (+9%) than did the model using only the tracking component.

Table 3. Regression coefficients and model equations; linear model for % omissions, cubic for RMS and standardized predicted values.
†: variable not in the equation

	R^2	p<	Age*B	Age*B^2	Age*B^3	const.
Vigilance % omissions	.091	.012	.494			6.634
Tracking RMS	.326	.001	†	-.00583	0.0162	12.608
Vig. & Tracking Std. pred. values	.402	.001	†	-.00046	2.3E-05	-.788

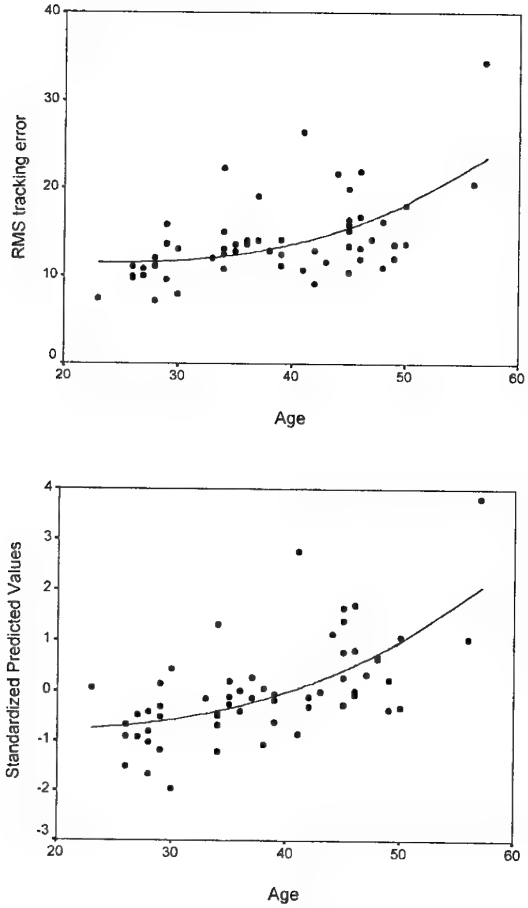

Fig. 5. Regression lines: tracking error (upper panel) and standardized predicted values (composite score, % omissions and tracking; lower panel) plotted against age and fitted with a cubic model.

Sleep at home and during stopover

All subjects considered themselves to be good sleepers when at home. Overall, no significant differences were found between younger and older pilots with respect of the various sleep parameters (Table 4). The night at home, before the outbound flight, sleep quality of younger pilots was slightly better, and total sleep time tended to be longer. During the stop over night, sleep latency of younger pilots appeared to be somewhat shorter, and older pilots tended to sleep longer as compared to home base. No significant correlations were found between age and the various sleep parameters.

Table 4. Mean scores on sleep quality, latency, and total sleep time, for younger and older pilots at home and during stop over nights.

	quality	latency (min)	total sleep time (min)
Home base			
younger pilots	1.9 (2.4)	26.7 (40.1)	457 (77)
older pilots	3.0 (3.8)	25.5 (36.6)	420 (85)
Stopover			
younger pilots	3.2 (3.5)	14.7 (13.6)	462 (98)
older pilots	3.4 (2.6)	25.2 (34.7)	465 (87)

CONCLUSIONS AND DISCUSSION

Using subjective and objective data from 3-day cross North-Atlantic operations, the influence of age on alertness and performance was investigated, and the possible co-related effects of sleep during the trip were analysed. During the entire operation, alertness profiles of younger and older pilots showed great similarity; both groups rated themselves as 'functioning at a high level' during the outbound flight, 'sleepy' before going to bed at the stopover hotel, and 'responsive' during the inbound flight.

Vigilance and tracking performance profiles were similar for both groups during the entire trip, but younger pilots performed significantly better. When correcting for baseline levels, vigilance performance was not affected by age, but, as compared to younger pilots, tracking performance of older pilots tended to deteriorate from the stopover night until top of descent of the return flight. What made them performing worse is unclear. Sleep quality and total sleep time were sufficient, and subjective alertness was at a normal level. But, when considering both performance parameters during the return flight, one could explain this finding by the fact that older pilots might have payed more attention to the vigilance task while younger pilots have put more effort into the tracking task. One have to keep in mind that the differences found account for the comparison between the two age groups. When comparing tracking performance of the older pilots on out- and inbound legs itself, no significant differences were found. This indicates that performance within this age group is at a comparable level on both flight legs.

The age-related effects found in this study are confirmed by the regression computations. Tracking performance showed to be significantly affected by age, while vigilance performance was not. This finding is in accordance with the study of Tsang (12). Braune and Wickens (1) examined the performance of pilots in tracking tasks and found a significant correlation between tracking accuracy and experience, but not between accuracy and age. If piloting an aircraft is regarded as a task comprising a major tracking component, this result is hardly surprising. Training and experience probably reduce or offset any negative effects of age. How far these findings also apply for this study population, is difficult to answer. The data did not allow for a differentiation into 'experience sub-groups' because of a very high correlation that existed between age and experience ($r = .923$, $p < .001$).

Although in this study no significant relationship was found between age and sleep quality and quantity, literature provides consistent evidence that this relationship exists (1,2,3) The pilots in this study population did not show differences between sleep at home and sleep during stopovers; they might be well adapted to their work schedules and/or might have had adequate rest and sleep opportunities. As a result, stopover sleep was sufficient to made them recover, and to perform at an adequate level during the return flight. However, operational demands and personal factors (such as age) might affect pilot's performance in such a way that an adequate performance level is not always self-evident. Therefore, it is recommended to keep focussing on adequate rest and sleep opportunities for pilots so that they can recover from increased fatigue due to these factors.

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Spinal Disease in Aviators and Its Relationship to G-Exposure, Age, Aircraft Seating Angle, Exercise and Other Lifestyle Factors

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ABSTRACT: ***Introduction***: Repetitive G-exposures during high-performance (HP) flying have a potential to accelerate the progression of degenerative spinal disease in aviators so exposed. (This concern was identified as needing further research in the recently completed RTO Technical Report 4.) Critical in determining the significance of these G-exposures is the selection of a control group as similar as possible in all other respects to the HP aviators studied. ***Methods:*** An anonymous survey was conducted to better establish the nature and degree of G-related spinal symptoms and disease. HP aviators at Spangdahlem AB, Germany were compared with a control group of nonhigh-performance (NHP) aviators living at Ramstein AB, Germany. Based on an extensive survey these groups were matched for all relevant demographic and epidemiological factors. ***Results:*** 161 surveys were distributed and 79 returned for a return rate of 49%. No greater incidence of chronic spinal symptoms or disease in the neck or lower back were reported in the HP group as compared to the NHP group. However, a majority of HP aviators (54%) did report acute spinal symptoms, especially neck pain, temporally associated with pulling G's, occurring either during or shortly after sorties. Twenty percent of the total number of HP aviators responding reported that neck symptoms limited their flying performance, including pulling G's, checking 6, and performing air combat maneuvers. Despite the increased seat angle slant in the F-16 as compared to the F-15, no significant difference in neck symptoms or performance limitations were reported as a result. Both HP and NHP aviators were noted in general to have good exercise habits with minimal use of tobacco. However, moderate use of alcohol was noted in both groups. ***Conclusions:*** Spinal symptoms, especially neck pain, were a common problem associated with HP flying and frequently limited flying performance though did not appear to result in any increase in long-term morbidity in this relatively young, predominantly male, group of aviators.

Index Terms: Aerospace Medicine, Aircraft, Aviation, Health Surveys, Military Personnel, Questionnaires, Risk Factors, Spinal Diseases

INTRODUCTION

With the progressively increasing performance capabilities of high-performance aircraft over the last several decades, there has been concern for spinal symptoms and spinal disease in aviators flying these aircraft. This concern is well documented in the NATO RTO Technical Report "Cervical Spinal Injury from Repeated Exposures to Sustained Acceleration" published in February 1999 (RTO-TR-4 published by the Human Factors and Medicine Panel) and is an area identified as needing further research.

Literature Review

Numerous previous articles have reported anecdotal spinal injuries in aviators of high-performance aircraft (1,5,9). Andersen et al. reported a case of a flight surgeon flying in the back seat of an F-16B who was apparently caught unaware during an abrupt 8 G climbing turn and suffered a C5-6 ligamentous injury. Schall reported a case of a pilot incurring fractures of three cervical vertebrae when during defensive aerial combat maneuvering in an RF-4C, negative Gz forces resulted in the pilot's head impacting the canopy. Hämäläinen et al. reported 3 aviators with cervical disk bulges associated with severe in-flight neck pain during aerial combat maneuvers under high +Gz forces.

Other articles have reported surveys which have addressed various aspects of the problem of spinal pain in aviators (4,6,7,8,11,12). Kikukawa et al. studied 129 Japanese F-15 pilots of which 115 (89.1%) reported neck pain related to flying and 44 (34% of the total surveyed) reported that these symptoms adversely affected flight duty performance. Knudson et. al. compared neck pain and injury in pilots of F/A-18, A-7 and A-4 in the U.S. Navy and Marine Corps and found of the 148 aviators surveyed, 89 (60%) reported neck pain during flight with an increase in both frequency and severity of the pain with increased G loads. Hämäläinen et al. also investigated the physical and lifestyle factors correlated with +Gz neck pain in 27 student fighter pilots and found that an increase in frequency of overall muscle endurance training (not specifically neck muscle exercises) was statistically

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associated with a decrease in incidence of +Gz related neck pain. Newman surveyed 42 F/A-18 pilots to determine head positioning techniques which may reduce neck pain during +Gz exposure and found that 29 (69%) used protective strategies including pre-positioning the head and/or bracing the head against aircraft structures prior to +Gz exposure. Vanderbeek performed a prevalence study using an anonymous survey questionnaire sent to pilots of F-5, F-15 and F-16 aircraft. The survey found that higher aircraft performance was associated with an increased injury prevalence and that increased pilot age was associated with an increased prevalence of major injury. Yacovane et. al. performed a survey of naval aviators along with a 10 year review of the Naval Safety Center personal injury reports (1980-1990) and concluded that the most common G-associated injury pattern was simple cervical muscle strain which posed a potential threat to combat readiness, but otherwise G-exposure was not a major problem. The study also found evidence that muscle-strengthening exercises may be helpful in prevention.

Other studies have investigated more objective determinants of spinal changes and spinal disease (2,3). Hämäläinen et al. performed low field (0.1 tesla) cervical MRIs on 12 fighter pilots frequently exposed to high +Gz forces and on 11 controls (ground personnel) matched for age and sex. While 11 of the 12 +G exposed pilots reported a history of in-flight neck pain, the number of pilots and controls reporting neck pain unrelated to G exposure during the prior twelve months was comparable (9 of 12 pilots vs. 8 of 11 controls). Nonetheless, a slight increase in the occurrence and the degree of disk degeneration was found among the pilots, especially at the C3-4 intervertebral disk space. Burns, Loecker et al. analyzed the findings on high-field strength (1.5 tesla) MRIs performed on the entire spine of 22 asymptomatic centrifuge subjects and 19 age and sex-matched controls. A small (statistically non-significant) increase in spinal disk abnormalities was observed in the centrifuge-exposed subjects. Intra-reader and inter-reader variability in MRI interpretation was found to be considerable.

METHODS

A comprehensive questionnaire was developed to survey a representative group of high-performance (HP) aviators along with a comparison group of nonhigh-performance (NHP) aviators. The nonhigh-performance aviators were chosen as a control group because it was believed that with respect to both physical and lifestyle characteristics this group would be similar to the high-performance group of aviators with the single exception of G-exposure. It was critical to the study that the nonhigh-performance aviators had as similar a lifestyle as possible to the study group. An extensive questionnaire was devised not only to address the numerous research questions but also to establish the degree of similarity between the two groups. The study addressed the specific spinal symptoms which occurred, the circumstances, e.g., increased +Gz exposure, checking 6, etc., during which they occurred, the effects of the symptoms on aviator flying performance, preventive techniques employed to prevent the symptoms, the effectiveness of such techniques and the other lifestyle factors which may be associated with and possibly contributing to the spinal symptoms. Aviators were also queried about any medical history of more objective spinal disease. Of particular concern were the effects of any symptoms on limiting flying performance even if these symptoms did not produce objectively determinable spinal pathology. The survey was anonymous to maximize the yield of frank and candid answers.

Another concern addressed by the survey was the significance of the 30-degree backward seat angle of the F-16 as compared to the 13-degree angle of the F-15. This increased seat angle of the F-16 may result in increased neck flexion in order to allow the pilot to see forward and, thus, an increase in stress concentration in the lower cervical spine. Such an increase in stress concentration could result in both an increase in neck pain as well as an increase in objective spinal pathology in the region.

Survey questionnaires were sent to the flight surgeons at Spangdahlem AB and Ramstein AB in Germany for distribution to the aviators at those bases. The HP cohort consisted of 81 pilots assigned to fighter squadrons (22nd FS, 23rd FS and 53rd FS) at Spangdahlem AB, Germany. The NHP cohort, i.e., flyers of tankers, transports and bombers, consisted of aircrew assigned to airlift squadrons (37th AS, 75th AS and 76th AS) at Ramstein AB, Germany. The aircrew were predominantly rated aviators, though several FCIII aircrew (loadmasters, aero-evacuation technicians and flight engineers, etc.) were also included. The questionnaires were distributed by the squadron flight surgeons for anonymous return by the participants upon completion. Approval for the study was obtained from the Advisory Committee for Human Experimentation (ACHE) at Brooks AFB and a survey control number (USAF SCN 9646) was obtained from Air Force Manpower and Personnel Center Survey Control Branch, Randolph AFB, TX.

Pearson's chi-square statistics for two-way frequency tables were used to make statistical comparisons. Kendall's tau b statistic was used for tests of statistically significant correlations.

RESULTS

Demographics
Of the total of 81 questionnaires distributed to the HP cohort at Spangdahlem AB, 35 questionnaires were

returned for a response rate of 43%. The specific return rates for the squadrons were 15 of 35 (43)% for the 22nd Fighter Squadron and 5 out of 23 (22%) for the 23rd Fighter Squadron, both of which fly F-16s and 12 out of 23 (52%) for the 53rd Fighter Squadron which flies F-15s. Thirty-five of the respondents were male and one of the respondents was female.

Of the total of 80 questionnaires distributed to the NHP cohort at Ramstein AB, 44 were returned for a 55% response rate. The respondents consisted of 35 pilots (10 in the C-9, 9 in the C-21, 8 in the C-130, 7 in the C-20 and 1 in the C-121), 4 flight surgeons (2 in the C-9, 1 in the C-130 and 1 in the C-20), 2 flight engineers (C-130), 2 aeromedical technicians (C-9) and 1 loadmaster (C-141). Thirty-nine of the respondents were male and 5 of the respondents were female (3 pilots, 1 flight engineer and 1 aeromedical technician).

The demographics for all aviators who responded are shown in Table 1. A comparison of the demographics for HP and NHP aviators is shown in Table 2. The mean age for HP aviators was 32.6 vs. 30.5 years for NHP aviators. The height (70 vs. 69 in.) and weight (178 vs. 173 lbs.) were also similar. The total military flying time (TMFT) was similar (2034 vs. 1786 hours) though the time in the current aircraft was significantly higher for HP aviators (1028 vs. 593 hours). Not surprisingly, due to the nature of the missions, the average flying hours per month and the average hours per sortie significantly differed for the HP aviators and the NHP aviators (17.9 vs. 26.6 hours per month and 1.3 vs. 3.3 hours per sortie).

Table 1: Demographics (All Subjects)

Variable	Mean	Standard Deviation	Range
Age (years)	31.4	4.5	21-44
Height (inches)	70	4.2	50-75
Weight (pounds)	175	20.9	120-210
Total Military Flying Hours	2102	1192	150-5000
Flying Hours in Current Aircraft	776	598	30-2900
Flying Hours per Month	23	7.9	8-50
Average Sortie Length (hours)	2.4	1.6	1-8

Table 2: Demographics (High Performance vs. Non High Performance Subjects)

Variable	Mean	Standard Deviation	Range
Age (years)			
High Performance (HP)	32.6	4.0	26-42
Non High Performance (NHP)	30.5	4.7	21-44
Height (inches)			
HP	70	3.0	60-75
NHP	69	4.9	50-75
Weight (pounds)			
HP	178	17.0	145-210
NHP	173	23.2	120-210
Total Military Flying Hours			
HP	2034	1029	300-4200
NHP	1786	1306	150-5000
Flying Hours in Current Aircraft			
HP	1028	653	100-2900
NHP	593	484	30-2150
Flying Hours per Month			
HP	17.9	4.3	8-25
NHP	26.6	8.0	10-50
Average Sortie Length (hours)			
HP	1.3	0.13	1.0-1.5
NHP	3.3	1.73	1.0-8.0

A comparison of the demographics of the F-15 vs. the F-16 aviators responding are shown in Table 3. Comparing the statistics for the two groups one can see that all characteristics are quite similar with exception of a minor increase in the total military flying hours (2317 vs 1880 hours) and a minor increase in the flying hours in the current aircraft (1243 vs. 900 hours) for the F-15 group.

Table 3: Demographics (F-15 vs. F-16 Pilots)

Variable	Mean	Standard Deviation	Range
Age (years)			
F-15	34.1	3.8	28-40
F-16	31.8	4.1	26-72
Height (inches)			
F-15	69.8	3.9	60-75
F-16	70.4	2.4	66-75
Weight (pounds)			
F-15	181.7	13.2	160-205
F-16	175.3	18.8	145-210
Total Military Flying Hours			
F-15	2317	714	550-3200
F-16	1880	1152	300-4200
Flying Hours in Current Aircraft			
F-15	1243	803	150-2900
F-16	900	525	100-2200
Flying Hours per Month			
F-15	14.6	4.1	8-25
F-16	19.7	3.4	10-25
Average Sortie Length (hours)			
F-15	1.2	0.1	1.0-1.5
F-16	1.3	0.1	1.0-1.5

Chronic Neck and Low Back Symptoms

The frequency of neck pain for HP and NHP was compared as shown in Figure 1. For this analysis, 2 aviators were removed from the HP category and 1 was removed from the NHP category due to a history of previous neck injury. Twenty-seven percent of the HP aviators report never having neck pain, whereas, 42% of the NHP aviators report never having neck pain. However, this difference was mostly accounted for by the difference in neck pain occurring a few times/year (36% vs. 21%). In fact, fewer HP aviators report neck pain occurring once per month or more than did NHP aviators (12% vs 16%). An analysis of this data using the chi-square statistical method with 3 degrees of freedom resulted in a value of 3.042 for a probability 0.385, not deemed to be statistically significant. Thus no significant difference in reporting of chronic neck pain for the HP vs. NHP aviators was found. A power analysis for detecting a similar hypothetical two-fold difference in neck pain revealed that this study had a 75% chance of detecting this difference at the 0.05 level of statistical significance.

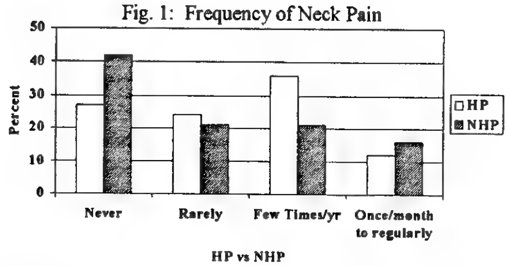


Fig. 1: Frequency of Neck Pain

The frequency of low back pain was compared for HP and NHP aviators as shown in Figure 2. In this case, 4 HP and 1 NHP aviator were removed from the analysis due to a history of previous low back injury. Of the 74 remaining (31 HP and 43 NHP), a chi-square analysis with 3 degrees of freedom resulted in a value of 0.371 for a probability of 0.946, not felt to be statistically significant. A power analysis for detecting a similar hypothetical two-fold difference in low back pain again revealed that this study had a 75% chance of detecting this difference at the 0.05 level of statistical significance.

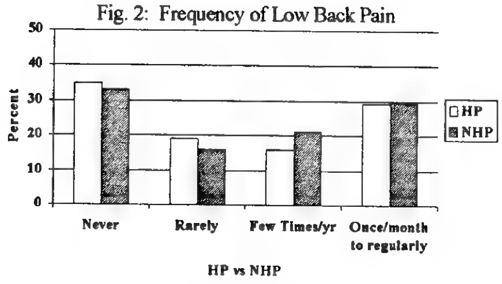


Fig. 2: Frequency of Low Back Pain

Also, of interest was the difference in spinal pain reported for the F-15 and F-16 pilots. Of concern was the 30-degree backward slanting seat angle in the F16 vs. the 13-degree angle in the F-15. The F-16 seat angle may result in an increase in neck flexion and, potentially, an increase in stress concentration in the lower cervical region, particularly at the C5-6 and C6-7 intervertebral regions where herniated discs are quite common. In contrast, the increased seat angle in the F-16 could cause the seatback to absorb more axial +Gz load that would otherwise be transferred to the lumbar spine in a more vertical seatback. Thus, there is a potential for an increase in lumbar spinal pain in the F-15 where such a load transfer does not occur.

A comparison of neck symptoms for aviators in the F-15 and F-16 aircraft is shown in Figure 3. One F-15 and one F-16 aviator were removed from the analysis due to a history of neck injury prior to flying their current aircraft. The chi-square analysis using 3 degrees of freedom resulted in 0.938 for a probability of 0.816, again, not statistically significant. In this case, the limited size of each of these aviator groups resulted in a power for detecting a two-fold difference in symptoms of only 40%. Similarly, a comparison of the reporting of low back pain for the F-15 and F-16 aviators using chi-square and 3 degrees of freedom resulted in 1.638 for a probability of 0.651, not statistically significant. A comparison of the data is shown in Figure 4. Again, a significant limitation in this comparison was the power of the analysis, which was 40% for detecting a two-fold difference.

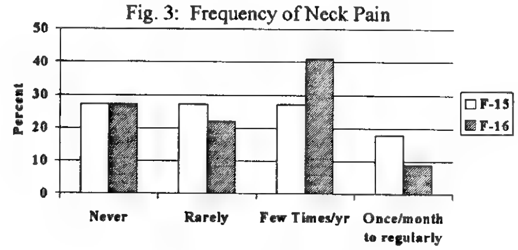


Fig. 3: Frequency of Neck Pain

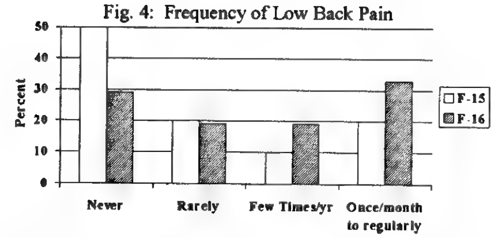


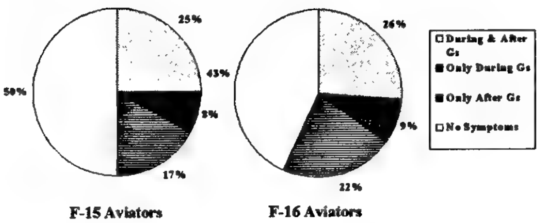
Fig. 4: Frequency of Low Back Pain

Acute Spinal Symptoms During and After G-Exposures

Despite the lack of a significant increase in reported neck pain unrelated to flying by HP aviators, many HP aviators did report neck pain temporally associated with G-exposures. Of the 35 HP pilots surveyed, 19 (54%) reported spinal symptoms occurring with

G-exposure, either during the exposure or shortly afterward. From the context of responses and associated comments the symptoms generally were neck pain and /or soreness. These positive respondents included 6 of the 12 (50%) F-15 pilots, three of whom had neck pain during and after G-exposures, one having neck pain just during the exposure and two reporting neck pain occurring only 2-8 hours afterward. Similarly, 13 of the 23 (57%) F-16 pilots reported G-related neck pain. Six of these pilots developed the symptoms during and after G-exposure, with 2 having neck pain just during G-exposure and another five having neck pain only 2-8 hours after exposure. As shown in Figure 5, the frequency of spinal symptoms in the F-15 and F-16 aircraft were, indeed, quite similar.

Fig. 5: Neck Pain or Soreness Associated with G-Exposure

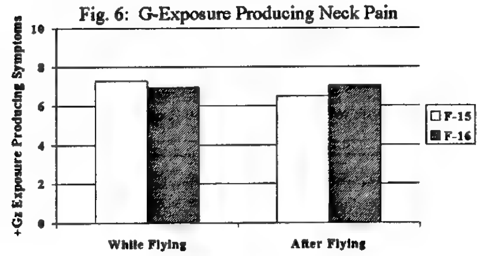


Most of the HP aviators reporting neck pain temporally associated with G-exposure wrote in specific causes such as "pulling G's, "BFM maneuvers", "turning head while pulling G's" and "head bent forward while pulling Gz's". For relief of symptoms, the majority of respondents reported that rest; heat and message; NSAIDS and sleep were beneficial. A few aviators specifically mentioned that reducing the amount of G-exposure was beneficial.

Of the 54 aviators commenting on techniques to prevent spinal symptoms (neck or lower back), almost all suggested some form of stretching or exercise as a means to prevent symptoms. Nineteen of the aviators referred to stretching that particular area of the body prior to flight. Twenty-two reported that general stretching exercises, especially those recommended by physical therapy, were helpful. Five reported that to prevent neck pain they pre-positioned their head prior to G exposures. Two relieved their neck pain by using pillows at night and two by improving posture. Three reported that nothing helps. (Some respondents provided more than one preventative technique.). For lower back pain, specifically, two aviators reported that using an increased number of lumbar supports while flying was helpful and one reported that lifting properly (unrelated to flying) was helpful. In summary, of the 54 aviators reporting techniques to prevent spinal symptoms, 40 (74%) specifically volunteered that some form of exercise, to include stretching, was helpful in preventing symptoms.

For those HP aviators reporting neck pain while flying, the mean G exposure at which symptoms of spinal pain occurred was 7.1 Gs (range 5-9) with a mean of 7.3 Gs (6-8) for the F-15 and a mean of 7.0 Gs (5-9) for the F-16 (Figure 6). The mean G exposure which lead to neck pain after flying for those HP pilots reporting this symptom was 6.9 Gs (5-9) with 6.5 Gs (5-8) for F-15 pilots reporting subsequent spinal pain and 7.1 Gs (5-9) for F-16 pilots reporting subsequent spinal pain. (One F-15 aviator reported that the G-exposure, which produced symptoms, depended on the positioning of his head.) With respect to the specific maneuvers producing spinal symptoms almost all of those responding specified checking 6 and/or rotating the head during G exposure, including basic fighter maneuvers (BFM) as contributing to neck symptoms in particular.

Fig. 6: G-Exposure Producing Neck Pain



Twenty-four of the 79 aviators (30%) sought medical attention of some form for spinal symptoms during their career. They consisted of 15 of the 35 (43%) HP aviators (5/12 or 42% of F-15 and 10/23 or 43% of the F-16 pilots) and 9 of the 44 (20%) NHP aviators. Every one of the 14 HP aviators who fully completed the survey question sought the initial medical care from their flight surgeon. In contrast, of the 9 NHP aviators seeking medical care, 3 (33%) sought the initial medical care from a provider other than their flight surgeon. This group consisted of one C130 pilot, one C21 pilot and one C9 pilot. Two of the three subsequently visited their flight surgeon for their symptoms. This small sample did not lend itself to a detailed statistical analysis. However, the findings do suggest that HP aviators are very compliant in using their flight surgeons for medical care.

For the 18 aviators completing information on the number of medical office visits required for spinal symptoms, the mean number of office visits was 3.7, with a mean of 1.5 visits to the flight surgeon and 2.2 visits to either chiropractors or other non-physician providers. Eleven aviators had spinal x-rays taken, all of which were essentially normal. (Two of these studies were interpreted as having "spinal misalignment" by a chiropractor.)

Six of the 35 HP aviators (1 F-15 and 5 F-16 pilots) reported having been grounded for spinal problems. In

contrast, only 2 of the NHP report having been grounded for spinal symptoms, both of whom had prior accidents - one being dropped from a hoist in survival school who had problems ever since and one aviator who had a traumatic cervical spinal fracture at age 22, apparently prior to entering uniform pilot training (UPT), which required spinal fusions.

Six of the 35 HP aviators (17%) reported loosing flying time annually due to spinal symptoms. The mean days lost per year was 5.5 days with a range of 2-14 days for the individuals reporting such annual groundings. Including those HP aviators not reporting annual groundings, the total group of 35 HP aviators' report loosing an average of 1 flying day per year due to spinal symptoms. In contrast, of the 44 NHP aviators, none reported loosing flying time annually due to spinal symptoms. Only two reported a history of previous grounding for spinal symptoms, both of whom had specific injuries unrelated to flying.

The age of onset of spinal symptoms was investigated. Seven of 12 F-15 aviators (58%), 11 of 23 F-16 aviators (48%) and 27 of 44 NHP aviators (61%) reported a history of having been bothered by spinal symptoms at some point in their life. The mean age of onset for the total group having symptoms was 25.6 years old (range 15-35). The mean age of onset was similar for each subgroup, 25.4 years for the F-15 pilots, 26.9 years for the F-16 pilots and 26.0 years for the NHP aviators.

Of concern was the possibility that spinal symptoms limited the flying performance of HP aviators. Of the 24 (of 35 total) HP aviators who reported neck symptoms, 7 (30% of those with symptoms) reported that these symptoms limited flying performance. For this group of 7 aviators, 3 (3/35 or 9%) reported limited the pulling of Gs, 5 reported limiting checking 6 and 4 reported limiting air combat maneuvers, particularly during BFMs, due to G-related spinal symptoms. Of the 17 HP aviators with neck symptoms who reported that flying performance was not limited, many volunteered comments such as "potential for hurting yourself while pulling Gs, but if careful, O.K" and "don't turn neck and be careful during high Gs" even though they specifically didn't report that the symptoms limited their flying performance. Thus, it appears that spinal symptoms significantly limit the flying performance of a significant portion of HP aviators, 20%(7/35) in this case.

Variation of Symptoms with Age and Total Military Flying Hours

Studies of correlations were performed to determine any association between cervical and lumbar symptoms and 1) age and 2) total military flying hours(TMTF). The later was used as an assessment of whether extensive exposure to high-performance flying resulted in an increase in degenerative spinal disease, and, consequently, an increase in spinal symptoms. Figures 7 and 8 illustrate the prevalence of reported cervical and lumbar spinal symptoms as a function of age. The NHP data is a measure of the effect of age alone, without the confounding influence of G exposures. In contrast, the HP data allows for the confounding effect of G exposures over time and, specifically, relates to symptoms in aviators in HP aircraft. Despite the minor upward trend in cervical symptoms with advancing age, particularly for HP aviators (Fig 7), statistical analysis revealed no significant correlation. Further evaluation was made of the power of the study. Due to the limited sample size, the estimate of the likelihood of detecting a 50% difference was only 20%. Thus, while there was no statistically significant correlation between neck pain and age in HP aviators, a trend was noted and likely would have achieved statistical significance if a larger sample size had been available.

Fig. 7: Age vs. Neck Pain

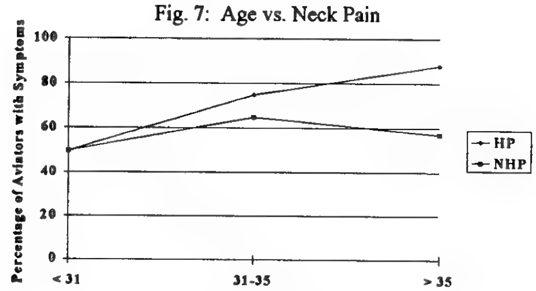
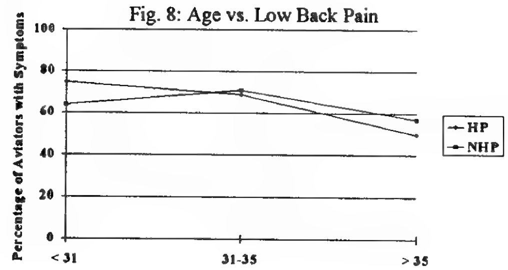


Fig. 8: Age vs. Low Back Pain



The relationships between the prevalence of cervical and lumbar spinal symptoms and TMTF are shown in Figures 9 and 10. TMTF was used to address the concern that repeated G exposures in HP aircraft may contribute to the progression of degenerative spinal disease and associated spinal symptoms. Again, no trend in increasing prevalence of spinal symptoms with increasing flying time was appreciated, suggesting that at least within the age group and range of flying time which this survey group represents, repeated G exposures do not result in a progression of symptomatic degenerative spinal disease.

Fig. 9: TMFH vs. Neck Pain

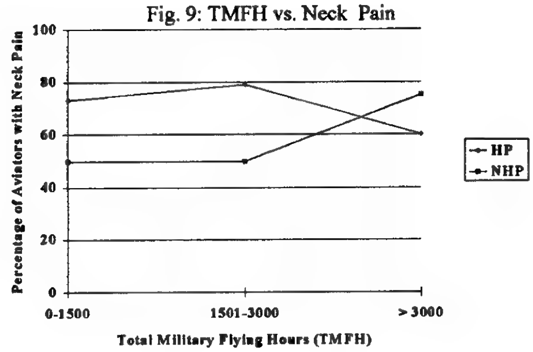
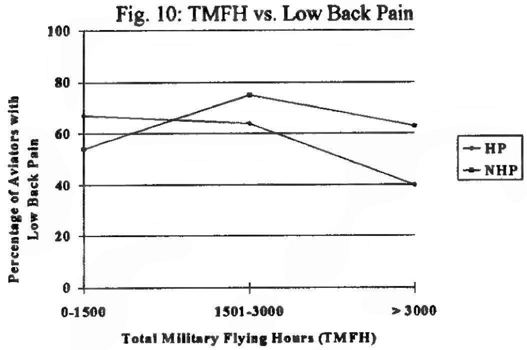


Fig. 10: TMFH vs. Low Back Pain



Exercise and Lifestyle Habits

Of the 78 aviators providing information on exercise, 74 (95%) reported performing some form of aerobic exercise at least once per week. Of the 71 aviators who specified the frequency of aerobic exercise, 44 of them (62%) performed aerobic activities at least 3 times per week. Thus, fully 59% (44/75) of the total group of respondents reported performing aerobic exercise at least 3 times per week.

With respect to HP aviators, 100% of those responding reported performing some form of exercise. 61% (20/33) of the HP aviators reported performing aerobic exercise at least 3 times per week, 21% (7/33) performing aerobic exercise 2 times per week, 15%(5/33) performing aerobic exercise once per week and 3% (1/33) performing only isometric exercise. 84%(28/34) of the HP aviators reported weightlifting at least once per week. Neck exercises, specifically, were performed at least once weekly by 50% (17/34) of HP pilots responding to the question. No significant difference in pattern of exercise was appreciated in comparing the F-15 and F-16 subgroups of HP aviators.

Of the 44 TTB aviators responding to the question regarding exercise, 93%(41/44) reported some form of exercise. Of the 42 providing information on the frequency of aerobic exercise, 60% (25/42) performed aerobic exercise at least 3 times per week, 21% performed aerobic exercise 2 times per week, 12% (3/42) performed aerobic exercise once per week and 7% (2/42) performing no aerobic exercise. In contrast to the 84% of HP aviators who weight lifted, 61% of the TTB aviator's weight lifted at least once per week. Only one of the 44 TTB aviators (2%) reported performing neck exercises, a 41-year-old C-20A pilot with a history of previous traumatic neck injury.

Eight of the aviators reported that specific exercises aggravated their spinal symptoms. 4 with neck pain (3 of who were HP aviators) reported that the use of weights aggravated their neck pain. Similarly, 5 with low back pain (2 of who were HP aviators) reported that the use of weights aggravated the condition. (One aviator had both neck and low back pain.) Two of the aviators with low back pain also reported that running aggravated their condition.

Another question addressed smoking habits. Of the 78 aviators responding to the question only 2 smoke (3%), both of who were flight engineers. Thus of the total of 73 rated aviators surveyed, not a single one reported smoking. A previous study by Dr.Vicky Voge observed a correlation between smoking and spinal symptoms (personal communication) but the low incidence of smoking in this study did not enable such an analysis.

Another question pertained to alcohol consumption. Of the 78 aviators responding to the question, 67 reported drinking. This consisted of 29 of 34 HP aviators (85%) and 38 of 44 TTB aviators (86%). The majority of aviators, 46 of 78 (59%), did not drink everyday. However, 32 of the 78 aviators responding (41%) had at least one drink per day. Five of the aviators (6%) reported consuming two drinks on average per day (one HP and four NHP pilots). None of the aviators reported consuming more than two drinks daily on a regular basis.

DISCUSSION

HP aviators reported significant neck pain associated with pulling G's, both during G exposure and for a few hours thereafter. Consistent with these reported acute symptoms, HP aviators as compared with the NHP aviators did have an increase in objective evidence of spinal symptoms including an increase in seeking medical care for these symptoms (43% vs. 20%), an increase in the annual rate of groundings (17% vs. 0% when excluding for a history of prior injury), and an increase in associated loss in annual flying time (1 vs. 0 days per year). However, there was no significant difference in reported neck or low back symptoms outside of the immediate effects of this G exposure. Similarly, in this relatively young group of aviators with a mean age of 31 and a mean total flying time of 2102 hours, there was no increase in objective pathology, such as abnormalities on x-rays, of which

the respondents were aware. . The onset of spinal symptoms in the subgroup of aviators reporting same was at the relatively young age of 26 years old and quite variable, ranging in age from 15-35 years old.

Within the HP group, comparing F-15 and F-16 aviators there was no significant difference in neck or low back pain. This suggests that the increased slant of the F-16 seat when compared with the F-15 seat is not a major problem with respect to spinal symptoms. However, the F-15 vs. F-16 comparisons were significantly limited by the size of these aviator subgroups such that a difference of two-fold or less in prevalence of symptoms was unlikely to be detected.

Importantly, neck pain tends to limit flying performance in the subset of HP aviators with such symptoms. Overall for the HP aviators, 54% had neck pain associated with flying, either during or shortly after sorties and was very similar for F-15 and F-16 aviators. For aviators with such symptoms, the mean G exposure producing such symptoms was 7.1 G's with a range of 5-9 G's and was very similar in both F-15's and F-16's. Specific flying activities reported as aggravating neck pain included BFMs, checking 6, head turning while pulling Gs and non-neutral head position while pulling G's, such as cervical flexion. Of the total of 35 HP aviators surveyed, 7 or 20% admitted to limiting flying maneuvers due to spinal symptoms. These maneuvers which were limited included pulling of Gs, checking 6 and/or air combat maneuvers, especially BFMs, due particularly to neck pain.

The HP aviators found that stretching, neck exercises and pre-positioning one's head prior to pulling G's are all effective in reducing G-associated neck pain. Lumbar supports tend to prevent low back pain in those aviators having such symptoms. For relief of neck or lower back pain, rest, heat and message, NSAIDS and sleep were found to be beneficial.

The reason for the finding of a somewhat lower compliance rate in flight surgeon use by NHP aviators is unknown and may be due to chance only. As the C-130 squadron at Ramstein has a squadron medical element (SME) similar to that of the fighter squadron groups at Spangdahlem, the lack of an SME is not the cause of this observation.

The exercise habits of this group of aviators is commendable, with 59% of the total performing aerobic exercise at least 3 times per week. Fully 95% of the aviators reported aerobic exercise at least once per week. This frequency of aerobic activity was quite similar for the HP and NHP aviators. The slight increase in weightlifting (84% Vs 61%) in HP aviators as compared to NHP aviators is consistent with the common use of weight training to enhance G-tolerance. The increase use of neck exercises by HP vs. NHP aviators support the commonly held belief that for a majority of HP aviators such exercise are helpful in preventing G-related neck symptoms. A minority of aviators with neck or low back symptoms reported that exercises using weight on that particular portion of the spine aggravated the condition. Also, running was reported as aggravating low back pain in two aviators with this symptom. Other health habits were quite impressive with none of the rated aviators surveyed smoking. In contrast, alcohol use was common within all subgroups of aviators with a significant minority drinking one or more drinks daily.

There were significant limitations in this study. First of all the sample size was small with a total of 79 respondents. This low n limited the ability of the study to detect small differences at statistically significant levels. Also, the 49% overall return resulted in an additional concern for potential systematic bias. For example, aviators with significant spinal symptoms may be more likely (or less likely) to complete the survey. Nonetheless, it is reasonable to assume that a similar pattern of behavior would occur for all aviators, whether HP or NHP. Therefore, while there is some concern regarding the values for absolute prevalence of symptoms, the comparative rates in different groups are felt to be valid.

Finally, the study fails to adequately address the effects of longer term G exposure. This issue would be better investigated by studies of older aviators more likely to have such symptoms or to have objectively determinable disease. This concern may be further addressed in a separate study including older aviators.

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DISCLAIMER

The opinions expressed in this paper are solely those of the author and do not necessarily reflect Department of Defense or Department of the USAF policy.

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DEGENERATIVE CHANGES OF THE SPINE OF PILOTS OF THE RNLAF

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The results of this study have been previously published in "Cervial spinal injury from repeated exposures to sustained acceleration. RTO Technical Report 4, 1999", and will also be published in Aviation, Space and Environmental Medicine.

Summary

Introduction: During air combat maneuvering under high $+G_z$ forces, the spine is frequently exposed to heavy loads. Therefore, acute in-flight neck injury is a common complaint among pilots flying high performance aircraft. However, not only sudden incapacitation is caused by high performance flying. The frequent and extreme loading of the spine over the years also constitutes a "chronic" strain, which can possibly lead to degenerative changes. In the "normal" population, the prevalence of spinal degeneration is associated with increasing age. However, this deterioration with age may be accelerated by regular exposure to high $+G_z$ forces. The aim of this study was to examine whether F-16 pilots are at an increased risk of (cervical) spine degeneration. **Methods:** Retrospectively, all pilots of the Royal Netherlands Air Force (RNLAF) that were systematically radiographed (at least twice) in the period between 1982 and 1994, were examined. In total 316 pilots were evaluated, 188 F-16 pilots (mean age 28.5 years at initial X-ray) and 128 pilots in the control group (mean age 24.2 years at initial X-ray). The control group consisted of 64 helicopter pilots, 63 NF-5 pilots and 1 F-27 pilot. None of this group of pilots had more than 150 hours flying experience with a F-16. Two radiologists, who were blinded as to whether the X-ray films were of F-16 pilots or control group, examined these X-rays separately. In both groups, the time between the two X-rays was on average 6 years. In these years the control group had a significantly higher mean number of flying hours compared to the F-16 group (resp. 922 versus 690 hrs). **Results:** Though the inter-rater agreement of the X-rays was rather low, both radiologists found comparable statistical significant differences between the two groups, on several levels of the cervical spine. In the F-16 group, an increased osteophytic spurring was found at levels C_4-C_5 and C_6-C_7, and increased arthrosis deformans was found in the cervical spine. Further analysis of the data of a selection of the total group of pilots, whereby the difference in age between both groups was minimized, showed that the higher mean age of the F-16 pilots was possibly correlated with the increased degeneration in this group. No consistent relationship was found between spinal degeneration and initial radiological status. Also, a clear relationship between spinal degeneration and flying hours could not be demonstrated. **Conclusion:** These findings suggest that frequent exposure to high $+G_z$ forces might cause premature degeneration of the spine of F-16 pilots. Future research has to demonstrate to what extent age, mission, and number of flying hours have influenced the results. An uniform international classification and coding system in combination with establishing an international data-base is recommended in order to more fully understand the relationship between exposure to high $+G_z$ forces and spinal degeneration.

Introduction

During air combat maneuvering under high $+G_z$ forces, the spine is frequently exposed to heavy loads. Above all, the harmful factor is the acceleration of the high performance aircraft. Together with twisted and extreme positions of the head, while wearing a flight helmet and oxygen mask with hose, the high $+G_z$ forces place an increased stress, especially on the cervical spine.

Paper presented at the RTO HFM Symposium on "Operational Issues of Aging Crewmembers", held in Toulon, France, 11-14 October 1999, and published in RTO MP-33.

Other aggravating factors are the poor sitting position of the pilot on the ejection seat and the vibrations of the aircraft, which are particularly marked in certain phases of the flight (taxi-ing, take-off, low-level flight, turbulence and landing).

A review of the literature has revealed numerous cervical spine injuries associated with high in-flight $+G_z$ forces, such as compression fractures, ligament tears and bulging of the intervertebral discs (1, 3, 8, 26). Acute in-flight neck injury is a common complaint among pilots flying high performance aircraft (17, 18, 21, 28). Not only sudden incapacitation is caused by high performance flying, the frequent and extreme loading of the spine over the years also constitutes a "chronic" strain (due to repeated instances of minor insult), which can possibly lead to degenerative changes (6). However, not much information is available on the long-term effects of exposure to high $+G_z$ forces on the spine.

In the "normal" population, the prevalence of spinal degeneration is associated with increasing age, already beginning in the third decade (4). However, this deterioration with age may be accelerated by regular exposure to high $+G_z$ forces (1). With the introduction of the F-16 in the Royal Netherlands Air Force (RNLAF), an increase in spinal column disorders was anticipated. Therefore, a systematical radiological examination of the whole spine was instituted in the medical screening since December 1982 (27).

The purpose of this study was to assess the effects of flying F-16 on spinal degeneration in RNLAF pilots, by using these X-rays, and to possibly relate spinal degeneration to initial radiological status. Also, the relation between total F-16 flying hours and severity of degeneration will be investigated.

Methods

Subjects

All subjects were pilots of the RNLAF, who were systematically radiographed at least twice in the period between 1982 and 1994. Between the two X-rays at least two years should have been passed. Both candidate student pilots and qualified pilots, designated to fly the F-16 since December 1982, took part in this study. Only those student pilots, who had no severe abnormalities at their first X-ray, entered the study population. This preselection did not occur in the older qualified pilots, because almost all of them were approved to be converted to the F-16, in spite of eventual deviations.

The F-16 group consisted of pilots having more than 150 flying hours in a F-16 between the two X-rays. Those pilots who had none or less than 150 hours flying experience with a F-16, entered the control group (64 helicopter pilots, 63 NF-5 pilots and 1 F-27 pilot). In total 316 pilots were evaluated; 188 F-16 pilots (mean age 28.5 years at initial X-ray) and 128 pilots in the control group (mean age 24.2 years at initial X-ray). These, and some other characteristics of the participants are summarized in Table 1.

Table 1 Subject characteristics

	F-16 pilots	control group	Significant difference
Number (no. females)	188 (1 female)	128 (7 females)	
Height (cm)	181 (167 - 193)	181 (161 - 191)	-
Weight (kg)	75.7 (60 - 98)	74.8 (48 - 100)	-
Age at initial X-ray (yrs)	28.5 (17 - 49)	24.2 (16 - 48)	**

values are mean and range in parenthesis,
* : significant at p <.05,
** : significant at p <.01,
- : not significant

Because of the higher mean age at the initial X-ray of the F-16 group, which can possibly interfere with the results, statistical analyses were also performed on a subgroup of the total population. A statistical equal mean age was obtained in the subgroup with an initial age between 20 and 30 years. This resulted in a group of 101 F-16 pilots and 67 pilots in the control group (mean age at initial X-ray resp. 24.2 years and 23.9 years).

Radiological examination

Two spine X-rays of every pilot were examined in this study, one initial and a second X-ray a few years later. Each X-ray consisted of 12 small films (circa 8 by 8 cm), which represented frontal and lateral views of the spine taken in standing

Table 2 Classification of disorders

	Disorder	Levels
General :	Osteo-arthrosis / Spondylosis / Arthrosis Deformans	Cervical, thoracic, lumbar
	Scoliosis	Cervical, thoracic, lumbar
	Abnormal alignment	Cervical, lumbar
	Scheuermann's disease / Enchondrosis	Thoracic, lumbar
Specific :	Degenerative changes in the intervertebral disc / Discopathy	Cervical, thoracic, lumbar
	Presence of Osteophyte's / Osteophytic Spurring	Cervical, thoracic, lumbar
	Presence of Osteophyte's posterior in spinal canal	Cervical, thoracic, lumbar

position. The X-rays were made with a 14 inch image intensifier, to reduce the radiation exposure to the candidate to 10-25% of that produced by conventional radiography.

Two radiologists of the Central Military Hospital, who were blinded as to whether the X-ray films were of F-16 pilots or control group, examined these X-rays separately. Both X-rays were examined in order of time, using the classification as mentioned in Table 2. The severity of the disorder was given on a 7 point scale (Table 3).

Table 3 Severity scores

Code 0	no abnormalities
Code 1	minor
Code 2	modest
Code 3	moderate
Code 4	rather severe
Code 5	severe
Code 6	very severe

Data analysis

The data were analysed using SPSS 7.5 and SYSTAT 7.0. Significancy was set at $p < .05$ (*) or at $p < .01$ (**). Statistic analysis was performed on the severity scores as well as on the difference scores, which reflect changes in severity scores in time. An overview of the statistical tests used in the data analyses is given in Table 4.

Table 4 Data analysis

Test for :	Statistical test :
1. Initial difference between the two groups	
- population characteristics	Student's *t* - test
- radiographical data	Somers' *d*
2. Significant change in time, for each group separately	McNemar's symmetry □ ^{2}
3. Significant difference between the two groups concerning changes in severity scores in time	Cochran's linear trend
4. Inter-rater agreement	Cohen's kappa

Student's *t* - test was used to study if there was a difference in population characteristics (i.e. age, height, weight) between F-16 pilots and the control group at the start of the study. To test whether a difference existed in severity of disorders between F-16 pilots and the control group at the start of the study, Somers' *d* was calculated. This is a measure of association for ordinal variables (r x c table), which has a column variable that is considered to be the dependent variable (in this study the severity score of the disorders is the dependent variable). A value of 0.0 means no association and 1.0 is indicating a perfect positive association (29).

McNemar symmetry Chi-square test was performed to determine the changes in the severity of disorders in the period between the two X-rays, for each group separately. For conclusions about differences between the two groups concerning changes in severity scores in time, Cochran's linear trend was used. Finally, Cohen's kappa was computed to study the degree of agreement between the two radiologists (inter-rater agreement). Values of kappa greater than 0.61 indicate good to very good agreement, between 0.21 and 0.60 means fair to moderate, and below 0.20 the strength of the agreement is poor (2).

Results

General results

Initially, the films of 346 pilots were examined. Because of unacceptable quality, it was not possible to judge the X-rays of 11 pilots. In 19 cases vital data were missing, so eventually the films of 316 pilots were used for statistical analysis. The removal of these 30 subjects was executed before classifying them in F-16 or control group.

None or only minor changes were observed at levels C_7-Th_1 and Th_{12}-L_1 and no further tests

Table 5 Subject characteristics

	F-16 pilots	Control group	Significant difference
Time between two X-rays (yrs)	6.13 (2 - 12)	5.77 (2 - 11)	-
Flying hours in this period (hrs)	690 (160 - 1900)	922 (200 - 2460)	**

values are mean and range in parenthesis,
* : significant at $p < .05$,
** : significant at $p < .01$,
- : not significant

were done on these levels. In this report no data will be presented for Scoliosis, Abnormal Alignment and Enchondrosis / Scheuermann's disease, because a significant relationship between these disorders and high $+G_z$ forces was not expected.

There was no difference between the two groups as far as the time between the two X-rays was concerned (on average 6 years), but during this period the control group had a significantly higher number of flying hours (resp. 922 against 690 hrs, Table 5).

Radiological results
The results of the test for initial difference, the tests for degenerative changes in time of the F-16 group (F-16) and the control group (C), and the final conclusions are summarized in Table 6. Only those levels are presented, demonstrating a significant difference between F-16 group and control group.

At most levels, there is a significant difference in severity scores between the F-16 and the control group at the first X-ray (third and fourth column). In all cases where an initial difference exists between both groups, higher severity scores are seen relatively more frequent in the F-16 group than in the control group.

In some cases, not only a significant change in time is found in the F-16 group, but also in the control group. In the last columns the final conclusions are presented. In most cases that a significant change in time was found in both groups, it was significantly larger in the F-16 group, and in these cases it is concluded that the degree of degeneration was higher in the F-16 group (degeneration F-16 > C).

In contrast to Radiologist II, Radiologist I not only found significant changes at cervical level, but also at lumbar level. At thoracic level only Radiologists II found Arthrosis Deformans. Agreement exists between both radiologists on levels C_4-C_5 and C_6-C_7 concerning Osteophytic Spurring and on general cervical level, concerning Arthrosis Deformans.

In Table 7, the frequency of changes in severity scores between the initial and the second X-ray are described for each radiologists separately, for those levels of the spine where both radiologists found significant degenerative changes. Absolute numbers as well as percentages are included in this table.

It can be seen that the frequency scores of Radiologist I are almost always higher than those of Radiologist II, except for Arthosis Deformans at cervical level. An arrow is marking those levels where agreement exists between both radiologists.

Selected group
As can be seen in Table 1, the F-16 group had a statistical significant higher age than the control group. In order to minimize a possible confounding effect of the age of the F-16 group, a second analysis was done on groups matched for age. By removing a relatively large number of pilots above age 30 out of the F-16 group, and a relatively large number of pilots below the age of 20 out of the control group, a comparable mean age was achieved in both groups. As a result, the mean age at initial X-ray of this selected group was 24.2 years for the F-16 pilots (n=101) and 23.9 years for the control group (n=67), which was not significantly different.

Table 6 Statistical results of the radiological disorders according to Radiologist I (Rad I) and Radiologist II (Rad II)

		Initial difference F-16 and C		*Degenerative change in time*				*Conclusion*	
				F-16		*C*			
		Rad I	Rad II	Rad I	Rad II	Rad I	Rad II	Rad I	Rad II
C_4-C_5	Osteophytic Spurring	F-16 > C	F-16 = C	**	**	-	-	degeneration F-16	degeneration F-16
C_5-C_6	Discopathy	F-16 > C	F-16 > C	**	**	**	**	degeneration F-16 > C	-
	Osteophytic Spurring	F-16 > C	F-16 > C	**	**	*	*	degeneration F-16 > C	-
	Osteophyte's Posterior	F-16 > C	F-16 > C	**	**	**	-	-	degeneration F-16
C_6-C_7	Osteophytic Spurring	F-16 = C	F-16 = C	**	**	-	-	degeneration F-16	degeneration F-16
C	Arthrosis Deformans	F-16 > C	F-16 > C	**	**	-	**	degeneration F-16	degeneration F-16 > C
T	Arthrosis Deformans	F-16 > C	F-16 > C	**	**	*	-	-	degeneration F-16
L_3-L_4	Osteophytic Spurring	F-16 = C	F-16 = C	**	-	-	-	degeneration F-16	-
L_5-S_1	Discopathy	F-16 = C	F-16 = C	*	-	-	-	degeneration F-16	-

> : significantly higher ($p < .05$), = : no difference, * : significant at $p < .05$, ** : significant at $p < .01$, - : not significant

Table 7 The number of pilots (absolute number and percentages) demonstrating an increase in severity scores in the period between both X-rays

	Radiologist I		*Radiologist II*		
	F-16 (%)	C (%)	F-16 (%)	C (%)	
C_4-C_5					
□ Discopathy	48 (26)	18 (16)	17 (9)	9 (7)	
□ Osteophytic Spurring	27 (14)	3 (3)	20 (11)	4 (3)	□
□ Osteophyte's Posterior	55 (29)	29 (25)	8 (4)	3 (2)	
C_5-C_6					
□ Discopathy	56 (30)	20 (17)	34 (18)	15 (12)	
□ Osteophytic Spurring	38 (20)	11 (10)	36 (19)	10 (8)	
□ Osteophyte's Posterior	61 (33)	27 (23)	23 (12)	4 (3)	
C_6-C_7					
□ Discopathy	22 (12)	12 (10)	17 (9)	4 (3)	
□ Osteophytic Spurring	32 (17)	4 (3)	18 (10)	4 (3)	□
□ Osteophyte's Posterior	23 (12)	13 (11)	8 (4)	2 (2)	
C					
□ Arthrosis Deformans	23 (12)	3 (3)	77 (41)	31 (26)	□

□ : change in time, values are numbers and percentages in parenthesis, □ : statistical agreement between both radiologists

In Table 8 the radiological results are summarized of both the total group as well as the selected group. Only those levels of the cervical spine are presented, at which significant differences were found between the F-16 pilots and the control group in the total group.

The initial differences between the F-16 pilots and the control group disappeared at almost all levels. In Radiologist I, it remained intact for Osteophytic Spurring at C_4-C_5 and C_5-C_6 and for Arthrosis Deformans on general cervical level. The results of Radiologist II showed no initial differences at all in the selected group. The conclusion of the results of Radiologist I is that the F-16 pilots show a significant higher degree of Osteophytic Spurring at C_4-C_5 level than the control group. This is not in agreement with Radiologist II, who found a significant higher degree of Arthrosis Deformans on general cervical level in the F-16 group compared to the control group.

Associations between variables

In order to evaluate the consistency of the radiological interpretations, the inter-rater agreement was computed for those levels, at which both radiologists found significant degenerative changes. The range of Cohen's kappa was 0.06 - 0.29 for the initial X-ray and 0.01 - 0.30 for the radiological changes in time, which means a poor to fair agreement between both radiologists. However, expressed as percentages, the range of agreement was 61 - 91 % for the initial X-ray, and 65 - 85 % for the change in severity scores.

In the F-16 pilots as well as in the control group, the number of flying hours between both X-rays decreased significantly with increasing age at initial X-ray, indicating a decreasing number of flying hours with increasing age of the pilot. However, the correlation was relatively low in both groups, respectively -0.20 in the F-16 group and -0.30 in the control group (Figure 1).

At almost all levels in the F-16 group, a higher age at initial X-ray was correlated with increasing degeneration in the cervical spine (Table 9). The values of the correlation coefficient's, at which significant relationships were found, varied between 0.16 and 0.35 in Radiologist I and between 0.19 and 0.36 for Radiologist II. In the control group, only in the data of Radiologist II significant correlations were found at some levels.

No consistent relationship was found between the changes in severity scores in time and the initial radiological status. Only at level C_4-C_5 both radiologists found a significant correlation for Osteophytic Spurring in the control group, and Discopathy at level C_6-C_7 in the F-16 pilots. At several other cervical levels significant correlations were found, but these correlations were low and there was no agreement between both radiologists.

Finally, no significant correlation could be found between the amount of flying hours in the time between both X-rays and cervical degeneration in this period.

Discussion and Conclusion

The results achieved in this study are in line with those expected. Previous studies have reported that high $+G_z$ forces might promote degeneration of cervical spine structures in addition to the effects of aging (1). Most of these studies, however, were not longitudinal, but merely compared F-16 pilots and a control group at a certain moment in time. Also, the limited number of subjects studied and the type of control group (e.g. unknown or non-pilots) restricts the impact of these studies.

Gillen and Raymond (12) demonstrated a significant deterioration in young pilot groups compared to a control group, in terms of Osteophytic Spurring at C_5-C_6 and disc space narrowing at C_4-C_5 and C_5-C_6. According to these authors, the $+G_z$ environment appears to play a role in an accelerated rate of cervical Osteoarthritis in high performance pilots, starting at a surprisingly young age (20 years and older). They hypothesize that the pilots, while remaining relatively asymptomatic during their flying career, may be at greater risk for symptomatic cervical disease later in life.

In a study of Hämäläinen (13), who used magnetic resonance images (MRI), disc degeneration among fighter pilots frequently exposed to high $+G_z$ forces was greater than among a non-exposed control group (age-matched ground personnel of the Finnish Air Force), the difference being the most remarkable for the C_3-C_4 disc.

Table 8 Statistical results of the radiological disorders according to Radiologist I (Rad I) and Radiologist II (Rad II), for the whole group (n=316) compared to the selected 'age-matched' group (n=168)

		Initial difference F-16 and C				*Conclusion*			
		Whole group		*Selected group*		*Whole group*		*Selected group*	
		Rad I	Rad II	Rad I	Rad II	Rad I	Rad II	Rad I	Rad II
C_4-C_5	Osteophytic Spurring	F-16 > C	F-16 = C	F-16 > C	F-16 = C	degeneration F-16	degeneration F-16	degeneration F-16	-
C_5-C_6	Discopathy	F-16 > C	F-16 > C	F-16 = C	F-16 = C	degeneration F-16	-	-	-
	Osteophytic Spurring	F-16 > C	F-16 > C	F-16 > C	F-16 = C	degeneration F-16	-	-	-
	Osteophyte's Posterior	F-16 > C	F-16 > C	F-16 = C	F-16 = C	-	degeneration F-16	-	-
C_6-C_7	Osteophytic Spurring	F-16 = C	F-16 = C	F-16 = C	F-16 = C	degeneration F-16	degeneration F-16	-	-
C	Arthrosis Deformans	F-16 > C	F-16 > C	F-16 = C	F-16 = C	degeneration F-16	degeneration F-16	-	degeneration F-16

> : significantly higher ($p < .05$), = : no difference, - : not significant

Table 9 Correlation between age at initial X-ray and the amount of degeneration of the cervical spine

	Radiologist I		*Radiologist II*	
	F-16	C	F-16	C
C_4-C_5				
☐ Discopathy	.08	- .13	.19 **	.04
☐ Osteophytic Spurring	.27 **	.13	.24 **	.04
☐ Osteophyte's Posterior	- .01	- .04	.20 **	.20 *
C_5-C_6				
☐ Discopathy	.32 **	.06	.36 **	.15
☐ Osteophytic Spurring	.29 **	- .04	.36 **	.15
☐ Osteophyte's Posterior	.22 **	- .16	.25 **	.09
C_6-C_7				
☐ Discopathy	.35 **	.10	.27 **	.27 **
☐ Osteophytic Spurring	.32 **	- .07	.32 **	.27 **
☐ Osteophyte's Posterior	.16 *	.10	.22 **	.21 *
C				
☐ Arthrosis Deformans	.33 **	.06	.36 **	.04

☐ : change in time, values are correlation coefficient's, * : significant at $p < .05$, ** : significant at $p < .01$

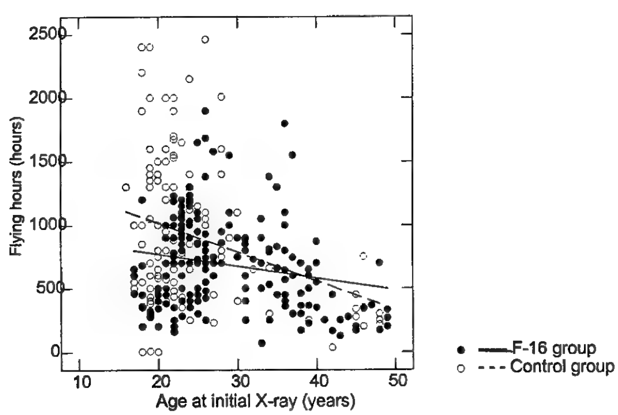

Figure 1 Correlation between age at initial X-ray and number of flying hours in the period between both X-rays

Petren-Mallmin and Linder (23) also found that military high performance flying might increase the risk for degenerative changes in the cervical spine. A significantly higher degree of disc protrusions per pilot was found and the mean sum of Osteophytes on the posterior border of the vertebral bodies also differed significantly from the control group. However, it was not mentioned whether the control group, who were sex- and age matched subjects, were also pilots.

One study found no significant difference between the MRIs of 22 asymptomatic male acceleration panel members and those of 19 age-matched control panel of asymptomatic male subjects (7). However, the power of the test was low because of the small sample size. Moreover, their confidence in the MRI interpretation was also low because of the high inter- and intra-rater variability.

In summary, there is some evidence that repeated exposure to high $+G_z$ forces might cause premature cervical disc degeneration (14). The repeated minor neck injuries may expose pilots to cumulative trauma and causing their spines, especially their cervical spines, to degenerate more rapidly than individuals not exposed to high $+G_z$ forces (1).

Moreover, there is a reasonable consensus about the most commonly involved site of cervical disc degeneration. In the general population, the frequency of cervical spine degeneration is greatest at C_5, followed by C_6 and C_4 (20). In studies of fighter pilots, the intervertebral disc at C_5-C_6, followed by C_6-C_7 were the most frequently affected sides (6, 9). Osteophytic Spurring was found most frequently at C_5-C_6 and disc space narrowing at C_4-C_5 and C_5-C_6 (12). The lower cervical spine appears to be most vulnerable to injury (7), which was also demonstrated in our study.

These findings suggest that frequent exposure to high $+G_z$ forces might cause accelerated degeneration of the cervical spine. However, the following considerations have to be made.

First of all, there are inconsistencies in the reading of radiographical data. Not only because of the lack of a uniform classification and coding system of disorders, but also because of the high subjectivity of the interpretation. This often leads to disagreements when different individuals report on the same films (1). A low inter-rater agreement is a common problem in radiography, and such was also the case in our study, although the agreement expressed in percentages in our study was reasonable high (61 - 91% for the initial X-ray, and 65 - 85% for the difference score). However, it must be mentioned that these numbers are flattered due to the high number of pilots having no radiological abnormalities. Cohen's kappa gives a better indication of the inter-rater agreement. The values found in this study were all below 0.40, which means a poor to fair strength of agreement (2).

Secondly, some methodological aspects may have influenced the results. Such as the fixed sequence of the films presented to the reviewer (always the initial films followed by the second), together with the fact that both radiologists were well aware of the purpose for which the examination was performed. Also, the assignment of the pilots to the F-16 or control group was based on the number of F-16 flying hours. The criterium of 150 flying hours or more was subjectively chosen, disregarding the nature of the flying missions and the experience of the pilot. Moreover, ideally the control group should have no fighter time at all.

A third, and very important item, is the overall radiographic degeneration of the spine with age. It is well known that cervical osteoarthritic changes occur with increasing frequency with increasing age in symptomatic and asymptomatic populations (12). These age-related degenerative changes possibly interfere in our study, because of the higher mean initial age of the F-16 pilots compared to the control group. This probably explains the initial difference between the X-ray scores at several levels of the spine, in favour of the control group. The results of the analysis of the 'age-matched' group confirm this hypothesis, because almost all initial differences between F-16 pilots and control group disappeared in this selected group, where the difference in mean initial age is minimized.

Although there are indications that a relationship exists between age and disc degeneration, there is no consensus about the nature of this relationship (10, 12, 16, 19, 25). Several studies demonstrate a roughly linear relationship, but it is also possible that, with increasing age, an acceleration of degeneration takes place which indicates that the relationship between age and disc degeneration is exponential.

Finally, several studies conclude that there is little correlation between radiographic findings and clinical symptoms of spinal disorders (1, 9, 15). According to Delahaye et al. (9) disc degeneration, even with very severe Osteophytosis, is often totally asymptomatic. The high incidence of spinal disc abnormalities in asymptomatic subjects has been well documented (7). So, when spinal films are used as a diagnostic tool, without correlating abnormal findings with specific symptoms, the radiological evidence has to be interpreted with great caution (3).

There was a small, but significant decrease in the number of flying hours in the period between both X-rays with increasing age at initial X-ray. This might be expected, because at higher age less flying hours will be made. However, especially in the F-16 pilots, a higher initial age is also related to increased cervical degeneration in the years between the two X-rays. As a consequence, no final conclusion can be drawn about the influence of the number of flying hours on spinal degeneration. Finally, a clear relationship between spinal degeneration and initial radiological status could not be demonstrated in this study, partly because of the low inter-rater agreement.

It can be concluded that, though the inter-rater agreement of the X-rays was rather low, statistical significant effects of F-16 flying were found. Increased Osteophytic Spurring was found at levels C_4-C_5 and C_6-C_7. Also, evidence for increased Arthrosis Deformans was found in the cervical spine. These findings suggest that F-16 pilots might have an increased risk of cervical spine degeneration. The results of an age-matched analysis are less striking, but differences between F-16 and control group are still present at some levels of the cervical spine. The results achieved here are in line with those from previous studies.

Recommendations

In the different member countries of the NATO, there is no consensus on the advisability of conducting systematic radiological examination of the spine at the time of acceptance or during the following years. Only a limited number of the NATO air forces carry out routine radiography of the spine (22), and the Royal Netherlands Air Force is one of them.

The results of our study suggest that it is recommendable to continue spine evaluations by means of radiography. Although the evidence is not strong, due to the low inter-rater agreement, there is some support that cervical spine degeneration can occur as a result of F-16 flying. Until more research has been done, it is advisable to continue the present procedure. The consequence of including radiographic examination in the initial screening of pilots is probably a higher rejection rate of candidate pilots. For example, in the period between November 1982 and January 1985, 20% of the Candidate Student Pilots of the RNLAF were rejected because of radiographically visualised spinal disorders, whether they had symptoms or not (27).

Instead of radiography, Magnetic Resonance Images (MRI) can be used. An advantage of MRI is that it does not involve exposure to X-rays, so radiation exposure will be minimized. Besides, the detection of disc degeneration using X-rays is difficult until quite severe (4). MRI is a far more sensitive imaging technique, which permits a definition of the earlier stages of degeneration (11). Unfortunately, the interpretation of MR images is much more difficult (1). It is excellent for delineating soft-tissue structures, such as the intervertebral discs, but the technique is less sensitive in defining osseous structures (5). Further, still let alone the costs, MRI being a fairly new and very sensitive diagnostic technique, it needs some time to establish reliable and reproducible interpretation criteria (7). To date, population-based statistics are not available for the entire spine using MRI (11).

So, despite the fact that MRI has a higher sensitivity and is less hazardous, plain X-rays might be more feasible for use in any definitive study (1). When using the image intensification method, as emphasised by Van Dalen & Van den Biggelaar (27), the radiation exposure will be greatly reduced.

To facilitate comparisons between the data from study to study, and country to country, it is advisable to standardize the format and description of anomalies. We propose to classify the results into categories of mild, moderate and severe disc degeneration, in order to improve the inter-rater agreement. Alternatively, the International Classification of Diseases Clinical Modification

(ICD 9 CM) could be used. This classification uses the terms mild, moderate and prominent (24).

Our results suggest to focus on the cervical spine, however, the cervical spine should not remain the exclusive focus of investigations of the effect of high $+G_z$ forces on the spine. High $+G_z$ forces may accelerate the normal degeneration process at all levels. For example at lumbar level, because more weight is put on this part of the spine as well. One of the problems in investigating the lumbar region is that back problems are extremely common in the general population (1).

For the prevention of injuries and also to increase the tolerance for high $+G_z$-forces, physical training is advised. Special physical training regimes for improving G-duration tolerance have been developed, and a subset of these training regimes consist of neck muscle exercise. The importance of these exercises should be emphasized (1).

In conclusion, more research is needed in order to establish the effects of frequent exposure to high $+G_z$-forces on the cervical spines of fighter pilots (21).

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ECG FINDINGS DURING CENTRIFUGE TRAINING IN DIFFERENT AGE GROUPS OF TURKISH AIR FORCE PILOTS

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INTRODUCTION

One of the important reasons for starting centrifuge training was that G-LOC was found to have an increasing role in aircraft accidents. Turkish Aerospace Medical Center began high sustained G (HSG) centrifuge training for jet pilots in 1991. ECG monitoring has been done from the beginning, but ECG data was collected for further research for only the last 2 years.

Cardiac dysrhythmias occurring during centrifuge training, which are physiologic responses to high acceleration, have been reported by many investigators (3-6). Sekiguguchi et al. (2) found that over 50 % of pilots from the Japanese Air Self Defense Force had dysrhythmias during high G training. Whinnery (7) has reported that treadmill stress testing and exposure to +Gz forces produce a comparable incidence of dysrhythmias, but that G forces have a tendency to produce more serious dysrhythmias, such as ventricular tachycardia.

These dysrhythmias usually are asymptomatic and resolve rapidly when the subjects return to 1-G environment. In this study we analyzed the ECG abnormalities occurring during centrifuge training (1).

METHODS

All pilots and pilot candidates are certified to Turkish flying medical standards, as a prerequisite for their duties. According to Turkish Air Force (TUAF) regulations, each jet pilot has to undergo centrifuge training every three years. During the last 2 years, 486 jet pilots and pilot candidates underwent high G training. All of them were healthy and passed cardiac test and physical examination.

The Centrifuge provides an average onset rate of 6 Gz per second from a baseline of 1.2 Gz to a maximum of 9 Gz. The centrifuge seat can be configured to resemble the seat in an F-16 aircraft (30-degree seatback angle and elevated rudder pedals) or in a conventional fighter aircraft (13-degree seatback angle). All trainees wore an anti-G suit. On the centrifuge, all pilots were monitored by means of ECG, closed-circuit television and continuous voice communication. Pilots did not wear a helmet or oxygen mask.

The high G training starts with a Gradual Onset Run (GOR) profile with an onset rate of 0.1 $G.s^{-1}$ to a peak of 8-9 +Gz. During this profile, the trainee pulls the stick back himself and sits relaxed while looking at the light bar ahead of him. This straight light bar is 71 cm long with a small green light (2.5-cm diameter) at each end. The center of this light bar has a 2.5-cm diameter red light. Then, as soon as he looses peripheral vision he should start to perform AGSM.

After a couple of minutes rest following the GOR, Rapid Onset Run (ROR) profiles are carried out with an onset rate of 6 $G.s^{-1}$. The first ROR is at +6 Gz for 30 seconds. During this profile, the trainee improves his AGSM under the supervision of the physiological training officer. The next ROR profile is at +7 Gz for 15 seconds. The final run is at 8-9 +Gz for 15 seconds, which is the training goal. During all runs, pilot controls the centrifuge (Fig-1).

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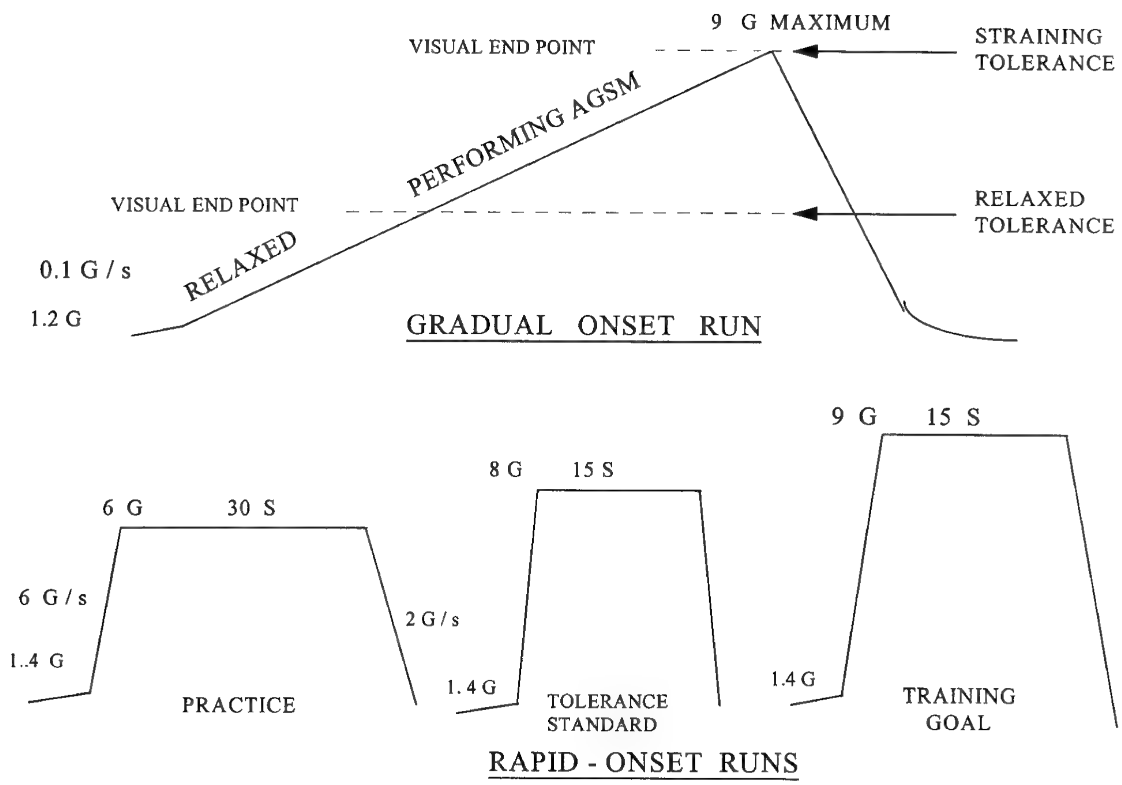

Figure 1: Rapid Onset Runs Profiles Used During Centrifuge Training

During these runs, two ECG leads (sternal and biaxillary) were recorded continuously at 25 mm/s throughout the training period and assessed by a cardiologist.

RESULTS

ECG tracings of good quality were achieved during GORs until the subjects started AGSM. However, artifacts became a problem during the intensive muscular contraction and unavoidable chest movement of the L-1 maneuver.

All tracings have shown sinus tachycardia during centrifuge run. The mean heart rate was 172 for the 22-30 age group at 6-7 and 8-9 Gz. It was 159 at 6-7 Gz and 162 at 8-9 Gz for the 31-42 age group (Table I).

Dysrhythmias were recorded in 143 (29.4%) of 486 fliers. The dysrhythmias classification was derived from the terminology used by the individual medical monitors when they recorded the dysrhythmias. It includes ventricular ectopic beats (VEBs), couplet VEBs , atrial ectopic beats (AEBs), supraventricular tachycardia (SVT), and sinus arrhythmia and sinus arrest.

The most common finding was ventricular ectopic beats (19.5% VEBs; 95 of 486). The 36% of the older group showed VEBs at 8-9 Gz. This rate was significantly higher than the younger group ($p< 0.05$).

Table I: Heart rates of pilot during centrifuge training

AGE	G - LEVEL	HEART RATE Between 110-140	Between 141-160	Between 161-180	Between 181-200
22 - 30	6-7 G (n : 229)	5 (2.2%)	47 (20.5%)	153 (66.8%)	24 (14%)
(n : 398)	8-9 G (n : 169)	3 (1.8%)	32 (19%)	120 (71%)	14 (8.2%)
31 - 42	6-7 G (n : 38)	8 (21%)	13 (34.2%)	14 (36.8%)	3 (7.9%)
(n : 88)	8-9 G (n : 50)	9 (18%)	12 (24%)	28 (56%)	1 (2%)

Couplet VEBs were seen in 6 fliers of 486(1.2%). AEBs were noticed in 15 fliers of 398 (3.8%) in the younger group. We did not see any AEBs cases in older group.

SVT was in 15 fliers (3%) and sinus arrhythmia was in 6 fliers (1.2%) of the total group. Sinus arrest was seen in 5 fliers of 398(1.2%) in the younger group (Table ll.).

Table II: ECG findings during centrifuge training

AGE	G - LEVEL	VEBs	Couplet VEBs	AEBs	SVT	Sinus Arrhytmia	Sinus Arrest
22 - 30	6-7 G (n : 229)	18 % (41)	-	3.5% (8)	4.8% (11)	2.6% (6)	1.3% (3)
(n : 398)	8-9 G (n : 169)	17.7 % (30)	1.7% (3)	4.1% (7)	1.2 % (2)	-	1.2% (2)
31 - 42	6-7 G (n : 38)	15.8 % (6)	2.6% (1)	-	2.6 % (1)	2.6% (1)	-
(n : 88)	8-9 G (n : 50)	36* % (18)	4 % (2)	-	2 % (1)	-	-
Total		19.5 % (95)	1.2 % (6)	3 % (15)	3 % (15)	1.4 % (7)	1 % (5)

(* $p<0.05$)

CONCLUSION: Centrifuge training may cause ECG abnormalities. Although these are common in high G environment, majority of them is not indicators of any cardiac diseases.

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TERRITORIAL ARMY AIRCREW – "THE SENIOR PILOTS" ARE THEY AT GREATER RISK?

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SUMMARY

This paper presents evidence of the operational effects of ageing on British Army aircrew in two areas: a restriction on flying (and other military duties) and accidents due to human factors. The data suggest that the age of Army pilots should not be reduced for operational reasons. There is an underlying trend that, given that pilots with serious medical problems will tend to self-select themselves out of the service reasonably early, the more experienced aviator is both safer in flight and a lesser burden to himself, and the medical services.

INTRODUCTION

Over recent years, there has been much discussion about risk analysis associated with aging. This is explicitly summarised by Tunstall-Pedoe[1] in which it was determined that the accepted rate of cardiovascular mortality at age 60 roughly equates to 1% per year or a 1×10^{-6} risk of sudden incapacitation in any hour. It is also accepted that the risk increases with age beyond age 60. However, the age-specific cardiovascular mortality among carefully screened aviators is not known, and it may be reasonably surmised that within this population the risk is probably lower. Furthermore, this "quantifiable risk of sudden death" which increases with age, is also dependant on many other risk factors (other than age) such as the individual's health status, smoking, blood pressure, gender, blood lipids, family history etc. The result is that the "unacceptable risk level" is probably reached in different individuals at different ages. The risk of incapacitation is less clearly understood for many other clinical conditions[2].

Stimulated by the title of this symposium and with an ever increasing awareness of the issues of aging in the workplace, we examined the effects of aging in the population for which we provide a comprehensive occupational health service - the British Army Air Corps.

The British Army Air Corps (AAC) is a small but potent aviation force of 290 helicopters. In April, 1999 there were 712 regular and Territorial Army (TA) aircrew. Fifty-two (7.4%) of these were aged over 50 and only 3 (0.43%) were over 55 years of age. The maximum age for commencement of pilot training is 28 for officers and 30 for non-commissioned officers. Entry medical standards are stringent and, as the majority is aged 23 –30 when they start flying, a "healthy worker" effect will be apparent. It is British Army policy that officers and other ranks will not serve beyond the age of 55. There are, as ever, exceptions, and aircrew above this age may be extended a year at a time on a case by case basis.

Most of the "older" generation pilots are employed either in staff and administrative duties, or as flying instructors - the latter particularly because of their extensive experience. They rarely present a medical challenge because of their age. Indeed, the highest rate of attendance at military medical centres is in the younger age groups (sickness admission rates for the British Army during 1997 were 180.8 per thousand for the under 20 age group, and 44.9 per thousand for the 50-54 age group).[3] However, those that are of potentially greater importance in an aeromedical context are the TA pilots. In the main, these are pilots who have retired from regular service although many are still in civilian commercial flying practice. They are employed either as aircrew in the TA AAC regiment, or as "pool" pilots who reinforce regular AAC units. It is perhaps the "solo-operations" nature of the task that they perform that requires us to regard them as a special risk occupational group. There has only been one recorded instance in which our increased concern

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has been realised (a myocardial infarction occurring in-flight), but nevertheless, by virtue of the increasing incidence of disease within this age group, they are worthy of a special interest.

Older pilots, by virtue of their experience, are thought to be of high worth to an organisation but the value of that experience is difficult to quantify. One area that is relatively easy to examine is accident rates particularly those involving aircrew error. Intuitively, accident rates should be lower with increasing experience and therefore also with age. Data from the US Army[4] suggest that this is so. There may, however, be negative factors associated with ageing in the aviation environment, such as slower cognition that counterbalances increased experience[5]. Li and Baker[6] found the rate of fatal accidents to be higher in pilots aged 50 years or older. In crashes of homebuilt aircraft those aged over 60 years accounted for 36% of those involved compared to 15% in general aviation[7]. However, Li et al.,[8] found there to be no significant age-differences in pilot performance factors involved in aviation crashes. Within the AAC, flying experience has been associated with aircraft crashes and it is believed that 500 hours flying represents a point at which the risk of crashing is high. However, this has neither been standardised for pilot's total flying time nor has the effect of age been examined. Therefore, although there may be more evidence to suggest that increased accident rates are associated with increasing age in civilian flying, the reverse may be true in military aviation.

In this study, we have chosen to consider the operational issues solely with regard to the capacity of the Army helicopter pilot to undertake and successfully complete his or her mission.

METHODS

The ages of aircrew were derived from personal records of the Manning Division at a single point in April 1999. As it has not been readily possible to obtain age distributions from previous years, the denominator to determine age-specific incidence rates in the analysis is therefore the present age-distribution. However, it does enable a reasonable estimate of the magnitude.

Two discrete sets of data were scrutinised to determine the incidence of significant morbidity and accident experience.

Morbidity data

Army aircrew must maintain a minimum medical standard to remain eligible for flying duties. Following an annual medical examination or at other times if it is warranted by their medical condition, Army aircrew are awarded a flying medical category (FMC). This is in addition to their Army PULHHEEMS Employment Standard (PES). It must be remembered that these medical categories are not punitive but protective (to both the individual and the Army's resources). The allocation of these grades should allow both the effective management of the employability (and deployability) of aircrew, and the ability of the medical system to monitor their clinical condition. The categories are summarised in table 1.

Table 1: Summary of medical categories

Category		Interpretation
PES	P2FE	Fit for combat. PES will be FE (forward everywhere).
PES	P3 LE	Fit for light duties. Unfit for combat duty. PES will be LE (Lines of communication).
PES	P7 HO	Fit for limited duties. Only fit for specific military employment. PES will be HO (home only)
FMC	A1	Fit for full flying duties
FMC	A2	Fit for full flying duties but either wears corrective flying spectacles, or has a hearing category of H2.
FMC	A3	Fit for limited flying duties which must be relevant to Army Aviation, and explicitly specified and/or qualified (e.g. "with pilot qualified on type." A waiver is applied to these cases.
FMC	A4	Fit to fly as a passenger only in military aircraft.

Notes: PES = PULHHEEMS Employment Standard
FMC = Flying Medical Category

The medical records were examined of all aircrew who had been medically downgraded to the categories of A3 and A4 and/or a PES of P3LE or P7HO between January 1989 and June 1999. The date of award of these categories was chosen as a marker to indicate the time at which a medical condition operationally affected the operational employment of aircrew.

These categories are employment markers that signify morbidity that has an effect on operational performance. Aircrew may have a PES which restricts them from terrestrial duties whilst they are able to fly in an unrestricted capacity within a defined theatre of operations (e.g. anterior knee pain syndrome). Whilst Army pilots are "soldiers first," it is the restriction imposed on flying duties that has the greater operational impact and thus gains the greatest attention from the AAC executive. Although the incidence of conditions resulting in both "unrestricted" and "restricted" (flying duties) are presented, we have concentrated on the operational impact of the latter. The null hypothesis for this part of the study was therefore that there is no difference in the rates of "restricted" disease between age groups.

Accident experience

A retrospective analysis of rotary wing accidents whose classified cause was "Human Factors Aircrew" (HF (A)) over a 35-year period was carried out in order to identify any association between age and accident rates. All accidents from the start of the AAC accident database in 1965 through 1999 were selected for inclusion and used to identify medical accident investigation files and the proceedings of the Boards of Inquiry. In turn, these were searched manually for crew age at the time of the accident and correlated were possible. In multi-crew aircraft, only the ages of the front seat crew were recorded.
The age distribution of pilots in the Army Air Corps in April 1999 was extrapolated back over the 35 years of the study to give the number of years flying in each age group. Thus, for example, thirty-three 27 year old pilots flying over the 35 year period amassed a total of $33 \times 35 = 1155$ years of flying. Accident rates with 95% confidence intervals using the SE (p) were then calculated for individuals (rather than formed crews) over 5-year age groups. A comparison with the accident experience of the U.S Army was also made.

The null hypothesis in this case was that there was no difference in the accident rate with changing age.

RESULTS

The age distributions for both regular and TA aircrew are illustrated at figure 1 and the summary data are shown in table 2. Age data are conventionally grouped in 5-yearly intervals with the fourth and ninth year forming the top of consecutive ranges. However, we have illustrated our data with the fifth and decade years forming the top of each range so that the normal Army retirement age (55) coincides with the top of the penultimate range.

Table 2: Summary of age distribution data

	number	Mean	SD	Range	95% CI
Regular Army	614	34.59	7.16	21-55	34.02-35.16
Territorial Army	89	44.36	6.54	31-57	42.98-45.74

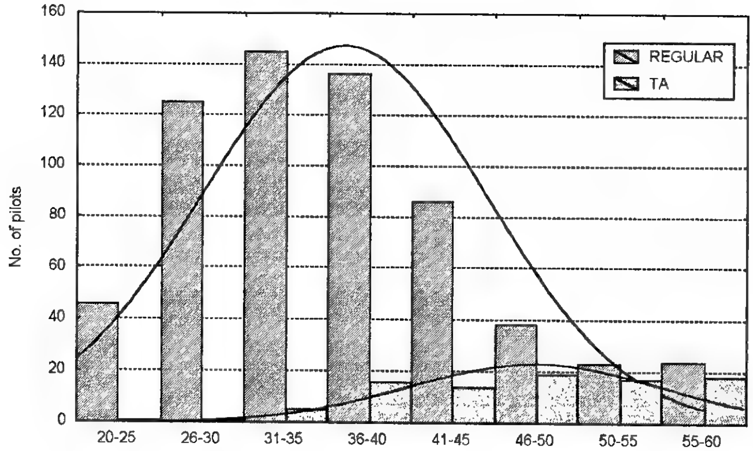

Figure 1: Age distribution of Army pilots (1999)

Morbidity

186 aircrew were downgraded between January 1989 and June 1999. For individuals in which there was coexisting morbidity both of which resulted in downgrading, the first condition to arise was recorded. Figure 2 summarises the clinical conditions.

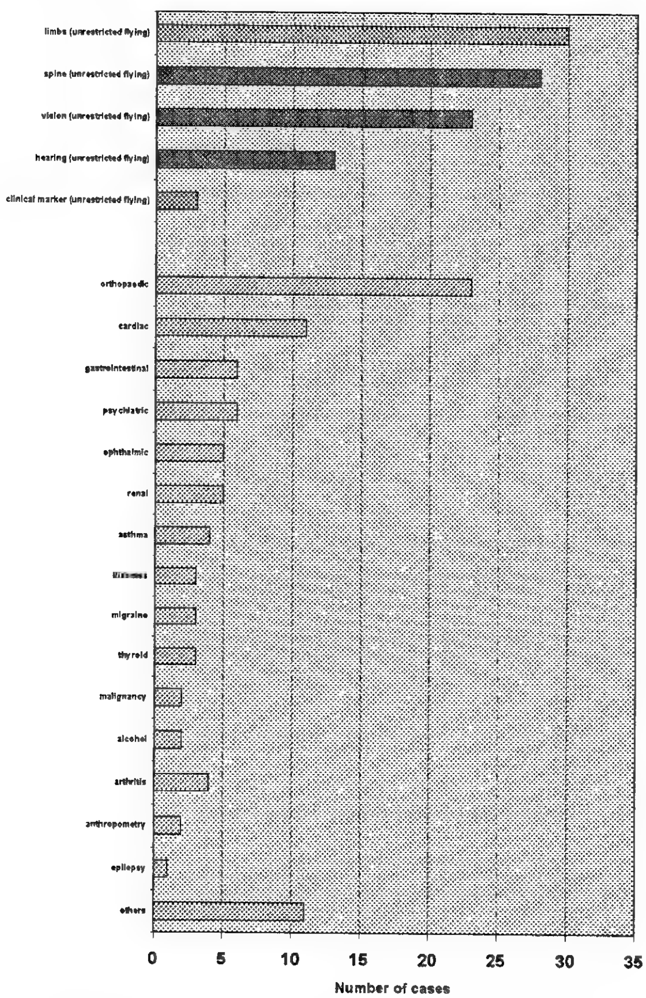

Figure 2: Clinical conditions leading to downgrading.

The incidence rates (by age group) for the most common conditions are shown in figure 3 (unrestricted flying duties) and figure 4 (restricted flying duties).

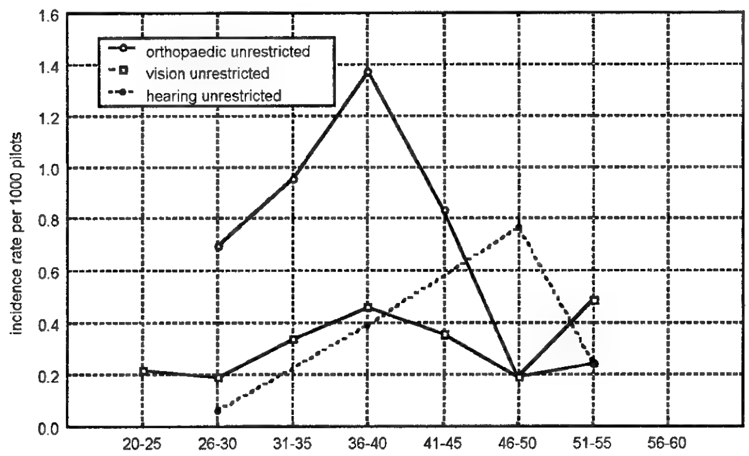

Figure 3: Incidence rate per 1000 aircrew of unrestricted" conditions

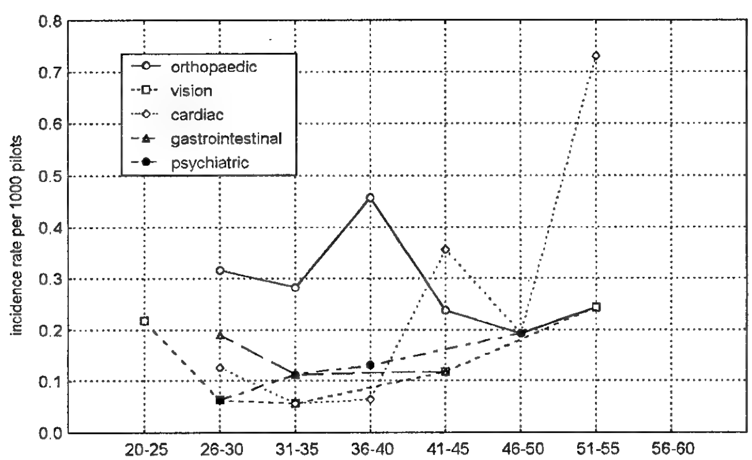

Figure 4: Incidence rate per 1000 aircrew of some "restricted" conditions

When the latter data are grouped together, an overall operational impact may be deduced. This is shown in the distribution of the age at which the initial restricted flying category was awarded (figure 5).

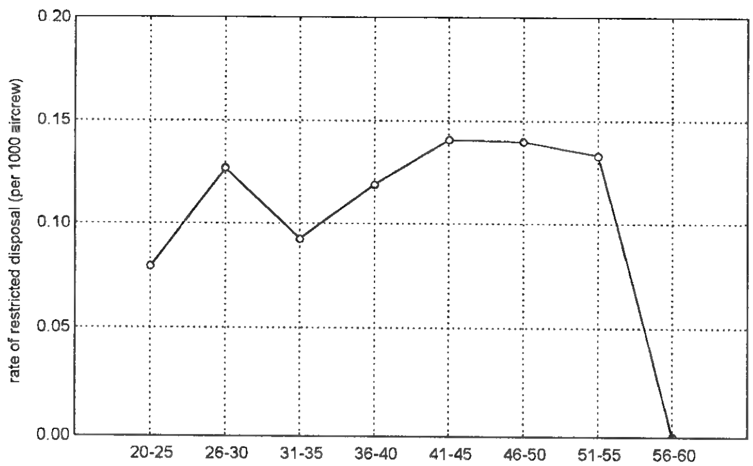

Figure 5: Rate of initial restricted flying category (by age group) (1989-1999)

The variation of both restricted and unrestricted flying categories by year within the age groups are shown in figures 6a & b.

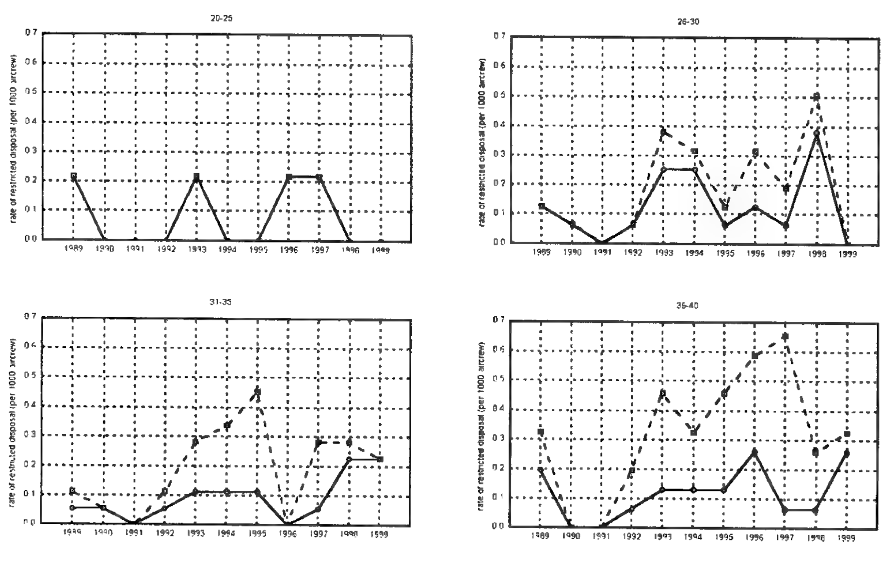

Figure 6a: Rate of initial restricted (solid line) and unrestricted (dashed line) flying category (by age group)

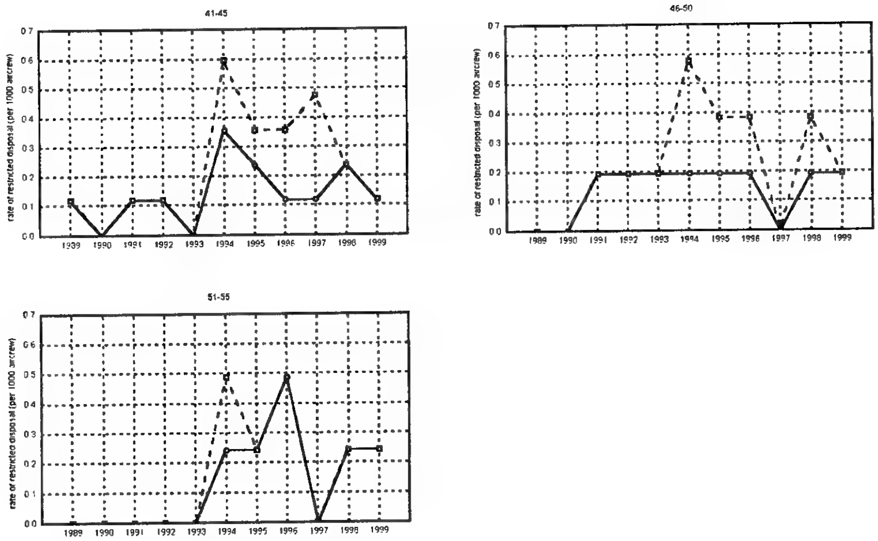

Figure 6b: Rate of initial restricted (solid line) and unrestricted (dashed line) flying category (by age group)

Accident data

Between 1965 and 1999, 135 aircrew were involved in 98 accidents. In 1999 there were 712 active pilots in the AAC. This therefore represents (712 x 35) 24920 years of flying. The overall accident rate was thus 5.42 accidents per 1000 years of flying. Only those HF(A) accidents for which no records could be found were excluded from the study. The outcome of the search is shown in Table 3.

Table 3: Profile for accidents included in the study

	Numbers
HF(A) group from database	111
Accidents removed due to incorrect coding	2
Un-coded accidents added	1
Total accidents 1965-99	110
Accidents for which records were found	98
Percentage of all accidents included in the study	89.1%

Table 4 and figure 7 show the number of accidents and the accident rates by age group. The accident rate is highest in the youngest group and decreases with increasing group age. The wide confidence intervals, particularly in the youngest age groups, mean that there is little significance in the change in accident rate between adjacent groups. There is, though, a significant reduction in the accident rate over the age range, with the youngest group being approximately twelve times more likely to be involved in a HF(A) accident than the oldest.

Table 4: Accident rate in Army Air Corps rotary-wing pilots by age group

Age (years)	Population (pilot/yrs flying)	Accidents	Rate (per 1000 flying yrs)	95% CI
20-24	840	11	13.09	± 7.69
25-29	5145	51	9.91	± 2.71
30-34	6405	47	7.34	± 2.09
35-39	5600	19	3.34	± 1.52
40-44	3150	5	1.59	± 1.39
45-49	1925	2	1.04	± 1.44
50-54	1750	0	0.00	
55-59	105	0	0.00	

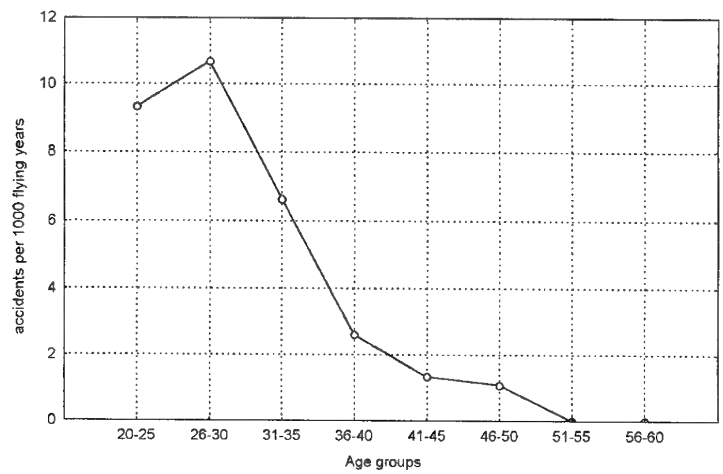

Figure 7: Human factors accident rate in Army Air Corps aircrew (by age group).

Figure 8 shows a comparison between the number of AAC accidents and those of the US Army. Even though the data illustrated are from different time periods, they show a remarkable similarity in trend.

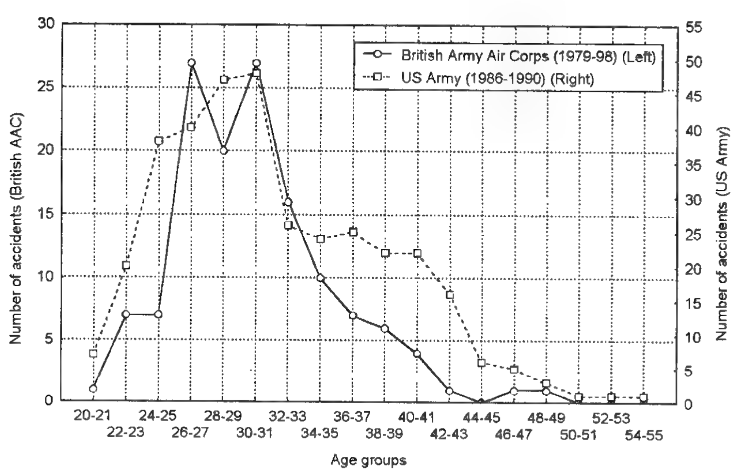

Figure 8: Comparison of British Army Air Corps and US Army Accident rates (by age group).

DISCUSSION

Although the data numbers are small, it can be seen that the incidence of clinical conditions resulting in a restricted flying category remains remarkably similar across the age groups (fig 5) until the 56-60 age group when it drops to zero. The latter may possibly be explained by the retirement policy in the Army - only those who are operationally fit are allowed to extend their service beyond the age of 55.

Orthopaedic reasons for a restricted grading dominate the majority of age groups. These conditions (in particular, postural spinal problems) are well known as a primary cause of military helicopter flying "disability."[9] The peak at age 36-40 probably reflects the stage at which the previously present disease process finally has an operational impact. Cardiac causes of restricted flying, most notably arrhythmia, not surprisingly have an increasing incidence with age. The visual causes of downgrading associated with the younger age group were invariably associated with injury, whilst the gradually increasing incidence with age is due to cases of glaucoma (and in some cases, the resultant aphakia). Gastrointestinal causes reflect the incidence of these types of disease in a young population - ulcerative colitis and Crohn's disease. The increasing trend with age of psychiatric causes is initially alarming except that the rate is very low (a total of 6 cases in 20 years) and may be explained by an increased incidence of "stress" affecting the older age groups.

Figures 6a and 6b illustrate that there are many cases of "terrestrial" downgrading that do not result in the diminishment of an aircrew medical category. This is especially true for the age groups ranging from 31 to 50. The majority of unrestricted cases are for orthopaedic reasons and the relative increase in downgrading over the last over 5 years probably represents a more effective management of the medical downgrading policy.

It is often presumed that as age increases, the incidence of illness also rises. While this may be true in the civilian population, our analysis reveals that the operational effect on military aircrew does not follow this pattern. In other words, increasing age does not have a significant operational effect on the flying task.

Only 19 of the TA aircrew were medically downgraded. Twelve of these had no restriction on their flying medical category, most being relatively minor conditions, e.g. waivers to allow them to wear corrective flying spectacles or because of noise induced hearing loss. The remainder were all graded "with a pilot current on type" for cardiovascular, neurological or ophthalmic reasons. Although a small number, this represents 7.9% of the TA aircrew population and, if not properly managed, could have a severe impact on TA AAC operations. Fortunately, all except two are within their last 2 years of service and have been retained for instructional and managerial duties rather than "active" flying duties. Despite their higher average age, there are less "with a pilot current on type" restrictions in the TA than in the regular Army. This may be explained as follows. First, most TA pilots are recruited from pilots leaving the service of the regular Army. To be eligible for TA service, they must have a current unrestricted flying medical category and therefore, the "healthy worker" effect is readily apparent. Second, the operational task that TA aircrew perform primarily involves solo pilot operations. Therefore, there is not the opportunity to continue to employ pilots in this restricted capacity.

It is a constraint of this study that the year by year age distribution of the AAC is unknown, and the use of the 1999 age distribution may have affected the results of this study. Over the last 15 years, there has been a tendency to reduce the age at which pilot training commences and this would tend to reduce the difference in both morbidity and accident rates. However, over this time frame there has also been a tendency to retain pilots for a longer period of service. This would act to inflate the differences. Overall, the combined effect is therefore thought to be minimal. Recording both crew members' ages in an accident involving a multi-crew aircraft is considered valid, as each plays a part in determining the fate of the aircraft. Even had this not been so, it is highly unlikely that an individual crew member could be singled out as the cause of an accident.

The strongest determinant of HF(A) accidents within this group would appear to be experience, with the youngest and least experienced aviators being the most likely to be involved in an accident. There were no accidents in the age range from 51-55 and neither were there any accidents in the range 56-60 years, although the denominator is particularly small in the latter case. Some 66.7% of Army Air Corps accidents have HF(A) as the primary cause.[10] This study provides strong evidence that at least up to the age of 54, and probably beyond that, the older aviator is the "safer" aviator. The data from the US Army are thus confirmed by this study, and it is likely that the military experience is different from that of the civilian flying population.

Within this review, it is pertinent to include the comments of the flying standardisation officers. They are firmly and unanimously of the following

opinions. In the current training and operational climate, the older aviator has a greatly increased number of flying hours compared to the relative novice. He has had more "check-rides," standardisation assessments, and has seen and experienced more. He is therefore trained and judged to be a better pilot. The standardisation team is however wary that in the future, particularly with the anticipated lower number of flying hours on the WAH-64 Apache attack helicopter, the aviator will get to be an older pilot with fewer hours.

THE IMPACT OF AGING ON FUTURE OPERATIONS

Compared to civilian flying, the AAC does not have the "luxury" of employing "multi-pilot crew. Even with a side by side cockpit, the consequence of incapacitation in military helicopter flying is much greater than civilian flying because of the low-flying nature of the task. In the WAH-64 Apache attack helicopter, the crew's roles are very different and they are tandem-seated. Therefore, one cannot regard the composition as a multi-crew, even though there are 2 members present. Nevertheless, the retention of the older aviator presents the opportunity for the greatest operational gain. Modern military helicopters are expensive; the WAH-64 Apache costs c.£30 million per airframe. This battle winning equipment will therefore be a scarce resource and it is possible that the older pilot is best placed to preserve the fighting power of a force simply by virtue of the fact that he or she is most likely to return the aircraft intact.

In conclusion, our study reveals that there is no evidence to suggest that the age of Army pilots should be reduced for operational reasons. On the contrary, there is an underlying trend that, given that pilots with serious medical problems will tend to self-select themselves out of the service reasonably early, the more experienced aviator is both safer in flight and a lesser burden to himself, and the medical services. They are also well attended by a flight surgeon and therefore, unless alternative evidence is presented, the aeromedical advice to the AAC will be to continue employing these aircrew in their current capacity, and thus to enjoy the operational effectiveness of our senior pilots well into the millennium!

Disclaimer

Any views expressed in this paper are those of the authors, and do not necessarily represent those of the Ministry of Defence.

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Age factor related to hypoxia tolerance

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INTRODUCTION

Hypoxia is one of the biggest challenges that we are facing with. We define hypoxia as the absence of adequate supply oxygen to the tissues. Humans are extremely sensitive and vulnerable to the effects of oxygen deprivation and severe hypoxia can cause a deterioration of the body's functions quickly, even death (1).

According to the ethiology we distinguish four types of hypoxia: Hypoxic Hypoxia is due to a reduction of the arterial blood oxygen, Anaemic Hypoxia is due to the reduction in the oxygen-carrying capacity of the blood, Ischaemic Hypoxia is the result of the decrease of the sanguine flow in the tissues and Histotoxic Hypoxia is the result of an interference with the ability of the tissues to utilize a normal oxygen supply for oxidative processes.

We include in the first type the reduction in the oxygen tension in inspired gas, associated with exposure to altitude, so-called Hypobaric Hypoxia. This is the most common form of oxygen deficiency in aviation.

The oxygen composition of the Atmosphere is constant, 20.09 %, but as the barometric pressure decreases with the altitude, the partial pressure of oxygen also decreases. Table I shows the atmospheric pressure and the partial pressure of oxygen in different altitudes.

HIGHT		PRESSURE (mmHg)	
Feet	Meters	Atmosphere	Oxygen
0	0	760	159.6
10,000	3,048	522.6	109.7
20,000	6,096	349.1	73.3
30,000	9,144	225.6	47.3
40,000	12,192	140.7	29.5
50,000	15,240	87.3	18.3

Table I.

Modern commercial aircraft fly at cruising altitudes from about 28,000 to 43,000feet (2). Although commercial aircrafts maintain a difference of pressure between passengers' cabin and the outside, in most of them, the pressure inside the cabin during the flight is between 5,000 and 9,000 feet over sea level (3), so passengers are exposed to a light Hypobaric Hypoxia. In military aviation, however, not all the aircrafts are pressurized and the level of pressurization is very variable.

Generally, the three main causes of hypoxia in flight are:

1. Ascent to altitude of a non-pressurized aircraft without supplementary oxygen.
2. Failure of the personal breathing equipment to supply oxygen with an adequate concentration or pressure.
3. Decompression of the pressured cabin at high altitude.

When a reduced concentration of oxygen enters the lungs, it diffuses less through the alveolocapillary membrane and then appears an hypoxemia that stimulates the periphery chemoreceptors, which inform the respiratory centre, and the respiratory frequency is increased. The hyperventilation increases the arterial oxygen tension and reduces the arterial carbon dioxide tension, this leads to a respiratory alluilosis and hypocapnia.

The absence of oxygen and the hipocapnia affect intellectual and psychomotor capacity and the alertness of individual. But the physiopathologic mechanism by which the hypoxia produces this cerebral illness, remains unknown. It is believed that the absence of oxygen and the oxidative failure reduces the synthesis of neurotransmitters and the acetylcholine metabolism (4).

The alterations can be very variable, but the two main problem in aviation is the lost of judgement (the individual in unconscious of the awareness deterioration) and of the lost of consciousness without previous symptoms.

These alterations will be more acute the higher the altitude reached. Many studies have demonstrated that the majority of the effects start from the altitudes between 5,000 and 6,000feet (1), although there can exist variable individual characteristics.

This individual variability will depend on many factors, for example, the individual capacity to compensate the changes in the cardiovascular and breathing functions; the changes in the dissociation of the oxihaemoglobin, the individual differences in the tissue capacity to tolerate the effects of hypoxia, etc.

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One of the factors that could influence the answer of the CNS to the effects of oxygen deprivation is age. We know that with age many of our cognitive and psychomotor capacities show a progressive decline. With age we become weaker and slower, for example, the writing speed falls in the third decade (20-29 years) and the capacity to learn and to remember also decreases (5).

However, we do not have knowledge that the central effects of oxygen deprivation, in different people, according to their age have been previously studied.

Therefore, the fundamental objective of this work is to study if, due to the age, differences exist in the performance and reaction capacity of healthy aircrew members, under hypoxia conditions. To carry it out we have quantified the degree of alterations of the cognitive functions, by means of a test completed during the flight training in a simulator of altitude or chamber of low pressure.

MATERIAL AND METHODS.

The physiological training is carry out in the Centre of Instruction of Aerospace Medicine (C.I.M.A.), and is done regularly by the fighting personnel of the Spanish Army every three or five years, depending on its specialty and destination, and in an isolated way in specialized courses. Previously each individual must overcome a medical check-up in agreement with the established medical norms for the psychophysical evaluation (6). Of these eligible personnel, we selected randomly and retrospectively (between 1993 and 1999) 161 cases. All the selected subjects had met the standards of regulation for flight in the Hypobaric Chamber, and had carried out the test of hypoxia demonstration during the training.

To carry out the training, a Hypobaric Chamber has been used. The Chamber is manufactured by Environmental Tectonic Corporation, model APTF 10M. In the course of the mock flight at 25,000 feet, after the necessary desnitrogenisation with oxygen to 100%, the subjects take off the oxygen mask and a Self-Demonstration Hypoxia Test (SDHT) begins. The *Duration,* in seconds, begins to count from the moment they take off their masks until they place it back again, either because they decide to put them on back voluntarily or because someone of the chamber crew indicates them for security reasons.

The SDHT, which appears in Figure 1, is a group of numbered tests that, the subject carries out without strict order. In the answers psychomotricity, immediate attention, short and distant memory, and the subjective symptoms that arise along the test are evaluated. From the test we obtain a *Punctuation* to each section according to their difficulty. The total sum of the *Punctuation* points could oscillate between 0 and 103 points maximum.

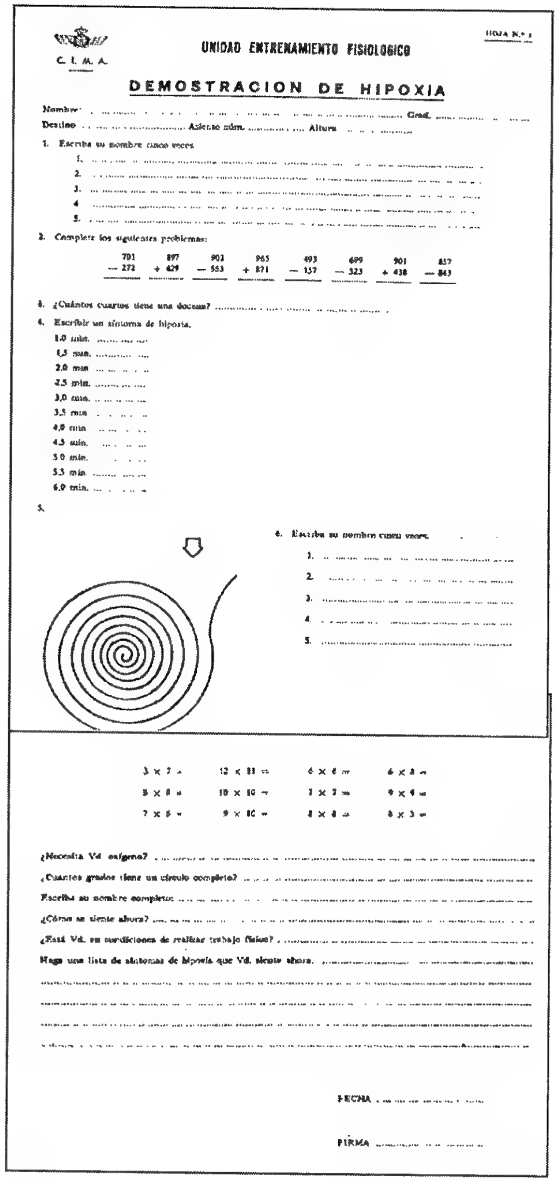

Figure 1. Self-Demonstration Hypoxia Test.

To give more objectivity to the results the variable *Speed* has been created. It is the result of dividing the points obtained by the duration of the test and multiplied by 100.

The following variables have been collected by the time the tests were done,:

- *Age.* We used this variable to create *Groups of age* including all the subjects in three groups: 20-29, 30-39 and ≥40 years.
- *Weight* and *Height.* Afterwards *Body Mass Index* was calculated (*B.M.I.*). The BMI is calculated dividing the weight in kilograms and the height squared in meters. According to the NIDDM European Consent, 1993, moderate overweight is considered between 25 and 30 in men and between 24 and 30 in women, severe

overweight between 30 and 40 and obesity above 40.

- *Tobacco.* We considered that "Smoke" those that habitually consume 10 or more cigarettes a day, and "Non-smoke" the rest.
- *Time.* This variable has two categories: "1st time" includes those that have not carried out the test previously, and in "2nd or 3rd time" those who have done so.
- *Professional Activity.* We reflect the influence of their habitual work over the hypoxia tolerance. This variable has three categories: "*Non-flyers*" includes the personnel who are related with the flight but fly exceptionally, "*Flyers*" includes the air crew members of a high performance or transport aircraft, and " Parachutists " those who practice parachuting.

The results of all the variables collected are introduced and analyzed using *Statistical Package for the Social Sciences* 6.0 *(SPSS)* computer software.

A descriptive study has been carried out of the variables, using the Kolmogorov-Smirnov test for the quantitative variables in order to test the adjustment to a normal distribution. It has been calculated the mean and the standard deviation (SD) for the quantitative variables and proportions for the qualitative ones. For comparison of means we used the "*t" of Student test, "u" of Mann-Whitney test* or *ANOVA* with *Bonferroni Test* according to the characteristics of the variables and Chi^2 for the comparison of proportions. Chance probability of "p" inferior or equal to 0.05 is accepted as critical for statistical significance.

RESULTS

The total number of subjects included is 161, of those 111 (68.9%) carried out the test for the first time, and 55 (31.1%) for the second or third time. The mean age is 33.43±9.16 years (range 20-55), for the analysis we have distributed the subjects in three age groups that are described in the Table 2.

Regarding to their professional activity the subjects are classified in three groups: "non-flyers" (28,0%), "flyers" (33,5%) and "parachutist" (38,5%).

The mean of BMI is 24.36 (DS 2.23), and using 25 as cutting point for moderate obesity we found a prevalence of this condition of 35.4%. There is a tendency of less-overweight in the younger ones and there is no association between BMI and professional activity.

31% of the subjects consume tobacco, being lower the prevalence among the younger ones.

The maximum *duration* of the test was 320 seconds and the minimum 75secs. (mean 176.57 DS 47.31).

The mean *punctuation* in the tests of tolerance to hypoxia was of 20.24 (DS 11.82).

The mean *speed* of realization of the test has been 11.45(DS 6.02) with a maximum of 45.33 and a minimum of 2.86.

When stratifying the participants for the fact of having carried out the test previously we found that the subjects that carried it out for the first time, were significantly younger (P=0.02). Significant differences were also observed when stratifying by the professional activity (p <0.001). These data appear in Table 3.

To study the association of the dependent variable " *speed* " with the rest of the variables collected, the cases were divided according to the variable *time*, because of the significant differences found between first-time subjects and those of 2nd and 3rd-time.

Among the subjects that carried out the test for the first time an association between the *speed* and the *age group* was found statistically significant (P=0.007). When applying the Bonferroni test it was found that those subjects between 30 and 39 years old obtained a significantly greater mean speed than those in the group from 20 to 29. These results appear in the Figure 2. For the rest of the variables collected (BMI, consumption of tobacco and professional activity) no associations with speed was found.

In the group of subjects that had previously carried out the test, an association was not demonstrated between speed variable and age groups, neither with any other variable.

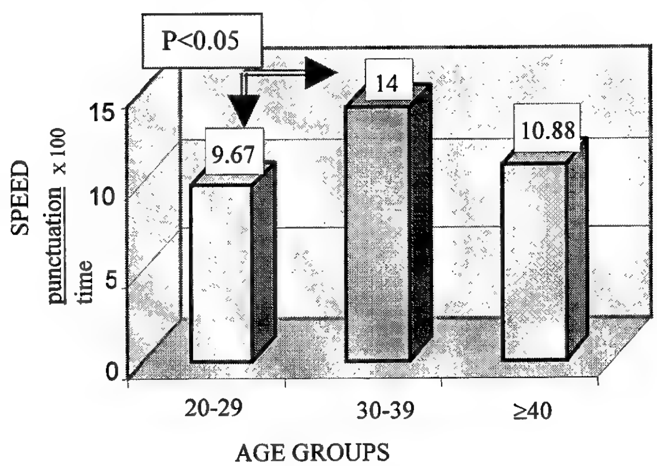

Figure 2. Mean speed by age groups.

Age Groups	N° of subjects	%	BMI	Professional activity	Speed
20-29	56	34.8%	23.64	Non-Flyers 48.9% Flyers 14.8% Parachutist 41.9%	9.77
30-39	55	34.2%	24.1	Non-Flyers 33.3% Flyers 20.4% Parachutist 46.8%	13.32
≥40	50	31.1%	25.45	Non-Flyers 17.8% Flyers 64.8% Parachutist 11.3%	11.26
Total	161	100%	24.36	Non-Flyers 28.0% Flyers 33.5% Parachutist 38.5%	11.45

Table 2. Age Groups.

		First time Mean (SD)	2^a or 3^a time Mean (SD)	Statistic Signification
AGE		32.58(9.45)	35.52(8.27)	P= 0.02
BMI		24.23(2.19)	24.65(2.33)	NS
SPEED		11.15(5.8)	12.10(6.41)	NS
PROFESSIONAL ACTIVITY	NON-FLYERS	32.1%	38.2%	P<0.001
	FLYERS	30.2%	53.1%	
	PARACHUTIST	37.7%	8.2%	
TOBACCO	NON- SMOKE	69.8%	67.3%	NS
	SMOKES	30.2%	32.7%	

Table 3. Comparison between the first and no first times that have done the test.

DISCUSSION.

The sample used for this study was picked out from the personnel of the Spanish Army related with the flight that came to the C.I.M.A. to carry out a physiological training in the hypobaric chamber.

Pilots generally begin their military career between 18-20, and must pass their physiological training in the low pressure chamber, to obtain their flight aptitude, before beginning to fly during their third course. After that, to continue maintaining the flight aptitude, they must do this physiological training periodically. For that reason the subjects that have done the test for the first time are statistically younger (p=0.02) that those that carry it out for second or third time.

The age that they stop renovating their flight aptitude is variable, although a representative age can be around 55, however, it depends on their profession. The pilots, usually, maintains his/her flight aptitude until this age, even though they've stopped flying, the parachutist and the personnel that do not fly, however, stop passing the physiologic training before.

According to the BMI in our study 35.4% are overweight. It was observed that a tendency of increase of weight existed with age.
This can be explained because to get admitted and during the first years of Military Academy they are demanded to be in good fitness.

On the other hand, no relationship exists between the BMI and the profession.

31% of the subjects consumes more than 10 cigarettes daily. It has been observed that a tendency exists to smoke more the older they get, although, it is not statistically significant. This can also be explained because the younger people maintain a better in shape.

To study the results of the SDHT, we measure the duration of the test, from the time the oxygen mask is removed until they put it on again, being very variable, between 75 and 320 seconds.

The Time of Useful Consciousness (TUC), defined as the interval of time between the interruption or decrease of the oxygen contribution and the moment that the subject is unable to carry out a certain task, in a precise and orderly way, is also very variable.

In the Table 4 we can observe the mean TUC and the Standard Deviation, calculated in 50 healthy subjects resting, breathing air at different heights (1).

ALTITUDE (feet)	TUC (seconds)	
	Mean	Standard Deviation
25,000	270	96
26,000	220	87
27,000	201	49
28,000	181	47
30,000	145	45
32,000	106	23
34,000	84	17
36,000	71	16

Table 4. Mean TUC related to the altitude.

Nevertheless, in our study we cannot consider the TUC, because the purpose of the training is that the crew member recognizes their own symptomatology under hypoxia conditions, but they do not have to reach the limit in the test. Some subjects put on their mask again voluntarily and others wait for the instructor's indication.

For this reason, a new variable, *speed* is obtained by dividing the punctuation by the duration of the test and multiplying by 100, to get, a more objective variable when studying the effects of the oxygen deprivation.

In our work, we have studied the results of the SDHT according to age, appearing significant differences when we only include the subjects that had carried out the test for the first time and no differences when we included those that had carried it out for the second or third time.

Using only the cases that carried out the test for the first time, the subjects with age between 30-39 years showed a greater speed, statistically significant ($p<0.05$) then those with 20-29 years of age and a tendency to a better answer than those >40 years, although not statistically significant.

Our results agree with the results of Kelman et al (11) who ran a test of selective attention to a control group of 18 subject at 2,000 feet and at 8,000 feet to another study group of 18 subject, finding significant differences in the realization of the test between these groups, however, when the 36 subjects familiarized with the test, those differences disappeared. In our work we have studied the results of the SDHT according to the age, appearing significant differences only when we include the subjects that had carried out the test for the first time.

Using only the cases that carried out the test for the first time, a better answer appeared, statistically significant ($p<0.05$) to the test. Calculated with the variable speed, among the second group (30-39 years) and the first one (20-29 years) and a tendency to a better answer between the second and the third (>40 years), although not statistically significant.

There are several publications where we can find examples that acute exposition to hypoxia produces alterations at the CNS.

Already in 1950, Scow et al. (7) checked this deterioration when carrying out some psychomotor tests in 17 subjects at 18,000 feet without oxygen supplement.

Fraser et al. (8) and Nordahl et al. (9), studying the postural control of 39 and 16 subjects, respectively, at different simulated heights, concluded that the affectation of the Vestibular System is a direct indicator of the effects of the Hypobaric Hypoxia in the CNS.

A more complex study was carried out by Vaernes et al. (10). They applied a test to study the cognitive and motor functions of 7 subjects at 10,000 feet high without oxygen supplement and they measured several endocrine hormones to determine the activation of stress. The conclusion was that after six and a half hours of exposition to hypoxia, alterations appeared statistically significant, mainly in the short term memory and in the time of visual reaction. However, the endocrine variables indicated that the stress was not the cause of these mistakes.

In spite of the great number of works carried out on this topic, we have not found any that study the relationships of these alterations with age.

The works that have been done studying the age factor in low pressure flights are those that aimed to demonstrate the decrease of the oxygen saturation with altitude.

Baker et al. (12) reached the conclusion that the desaturation is an important factor in accidents of non pressurized light planes. They carried out a study on the disproportionate number of accidents of light planes in the mountains of Colorado, observing that the cause of many of these accidents was that the pilot loses his of critical opinion, when flying above 14,000 feet without using oxygen.

Cottrell et al. (13) suggest that the great variability in the effects in the CNS in hypoxia conditions, is related to the level of oxyhaemoglobin saturation. They studied 42 air crew members at 8,000feet, the oxygen saturation, measure with an oxymetre, oscillated between 93 and 80%. However, they did not find relationships between these levels and age.

Bendrick et al. (3) studied 29 patients with Obstructive Chronic Lung Disease, when being evacuated in an airplane with cockpit altitudes oscillating between 5,000 and 9,000 feet, finding that the decrease of the oxygen saturation with altitude, measured with an oxymetre, had no relationships with age.

The inconvenience of this method is that the oxymetre does not measure the levels of carbonic anhydride and therefore it does not indicate the dysfunction due to the hypocapnia and also it does not differ between the carboxyhaemoglobin and the oxyhaemoglobin.

However Dillard et al. (14) studied the decrease of the oxygen saturation with a gasometry of a radial artery in 42 subjects during an exposition to hypoxia, and in this case they also did not find any relationship between the oxygen saturation and the age.

These results do not agree with ours, in our sample the subjects between 20 and 55 years, we have found that those that are between 30 and 39 years tolerate better the hypoxia, even if, as we have pointed previously the younger ones were in better shape.

We think that this is because this age group has accumulated experience and still has not suffered the deterioration of the cognitive and psychomotor capacities related to aging.

We have not found any relationship between the speed and other variables such as BMI, tobacco or professional activity. Although it may seem logical that the subject with overweight or smokers respond worse to the hypoxia, and other authors have demonstrated it in their works (13, 15), we have not obtained any difference. This cold be explained by the small sample size.

The professional activity is not related to the hypoxia tolerance, although the pilots and the parachutists are more used to hypoxia and they should tolerate it better than the group of those that are not habitually flyers. The fact that neither the physical conditions neither professional practices it they influence in the answer to hypoxia, he/she reinforces even more the age factor.

However, our study has several limitations, first of all, the original purpose of the test is to teach the subjects to recognize their own symptoms when exposed to an hypoxia atmosphere, therefore the test is not designed to quantify alterations.

In conclusion, our data suggest that the subjects in the age group of 30 to 39 years tolerate the hypoxia better, although it will be necessary to carry out new studies with more precise methods to be able to clarify the meaning of our observations.

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TIME OF USEFUL CONSCIOUSNESS IN CREWMEMBERS DURING HYPOBARIC CHAMBER FLIGHTS

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MATERIAL AND METHODS – The authors studied the times of hypoxia in 43 Portuguese Air Force military people, during hypobaric training chamber flights.

The times where measured since the moment the trainees took off the oxygen mask until they began to breath again 100% oxygen, this time being considered as the time of useful consciousness.

The hypobaric chamber flights take place during the basic and refreshment physiological training courses of our crewmembers, according STANAG 3114.

The flight is preceded by a period of denitrogenation of 35 minutes. During this period we go to 5,000 feet and after to sea level, at a rate of ascent and descent of 5,000 feet per minute, to perform a ears and sinus ckeck.

The hypoxia demonstration is accomplished at 25,000 feet, after a rapid decompression that takes place between 12,000 and 19,000 feet.

The duration of hypoxia demonstration is due to safety reasons usually limited to a maximum of 5 minutes. After this demonstration we performed another one to show the reduction of visual acuity at night, under hypoxic conditions. This demonstration is performed at 18,000 feet.

During the hypoxia demonstration we want the crewmembers to memorize their symptoms, by order of appearance, and this is anither reason why we limit the time of exposure to 5 minutes.

Simultaneously with the withdrawal of the masks we deliver to the trainees a form to fill. This form was prepared by the Psychology Centre of the Air Force, and with it we try to demonstrate the cognitive-motor degradation that appears with the lack of oxygen.

After the demonstration the Physiological Training Officer in charge discuss with each of the trainees their symptoms and their order of appearance.

This study was made with trainees of different groups: pilots, other crewmembers, flight surgeons and HALO paratroopers from the Portuguese Army.

The trainees were 7 females and 36 males, with ages between 25 and 44 years (mean age of 32,24 years); 33 were no smokers (ages 25 to 44 years) and 10 smokers (26 to 38 years).

RESULTS – the results we obtained can be seen in the following table:

	Min. time	Age	Max. time	Age	Mean time
Smokers	2' 34"	26	5' 46"	34	3' 55"
Non smokers	1' 35"	30	4' 55"	32	3' 43"

CONCLUSIONS ANS DISCUSSION – the results obtained in this study seem to point, in general, for an absence of a significative difference between the hypoxia time, age or smoking habits.

Nevertheless, some isssues can be discussed:

1 – the small number of this sample is the first one; we continue to collect data from the hypobaric chamber flights to try in a near future, publish more results to complete these ones, in a effort to understand the connection between the hypoxia times and age, smoking habits and gender.

2 – what we have considered the time of useful conscousness, was the time that have mediated between the beginning of hypoxia demonstration and the moment when the trainees began to breath again 100% oxygen.

3 – the times of hypoxia collected show some variations that we can connect to anxiety, like the crewmember aged of 30, non smoker, that had a time of 1' 53". He was attending a Basic Physiological Course, he was not a pilot and it was his first contact with the hypobaric chamber.

4 – no one of the hypoxia times was correlated with the number of blood red cells of the individual. An explanation we can find is the high number of those cells seen in chronic smokers.

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PULMONARY FUNCTION IN A DIVING POPULATION AGED OVER 40 YEARS OLD: A CROSS-SECTIONAL STUDY.

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ABSTRACT: Professional military divers are exposed to high pressure levels during long time. This high pressure is going to have an effect over the diver and over the respiratory mixture that is going to breath. The consequences of this high pressure level are the following: High oxygen partial pressure, an increase in the density of the mixture that will be proportional to the depth. All these different aspects can produce modifications in the pulmonary volume and flows that can be observed by spyrometric test. OBJECTIVE: To evaluate the pulmonary function and the mechanism of pulmonary adaptation of a group of military divers overs 40 years old by a spirometric test. MATERIAL AND METHODS: A group of 23 males professional military divers who belong to the CENTRO DE BUCEO DE LA ARMADA (CARTAGENA-SPAIN). 8 of them were smokers and 15 were nonsmokers. We studied the following parameters: FVC, FEV1, FEV1/FVC, FEF 25-75, FEF75-85. RESULTS: FVC% (104.87), FEV1% (98.60), FEV1/FVC% (77.52), FEF 25-75% (90.87), FEF 75-85% (82.65). CONCLUSIONS: Divers aged over 40 years old show larger lung capacities than normal population, whereas parameters which indicate airway obstruction are decreased. This fact leads to consider the presence of an asymptomatic obstruction of small airways.

INTRODUCTION

During the performance of their professional activity, divers are exposed to an environment for which they are not physiologically prepared. The continuous action of various factors favours the appearance of changes in different organic structures. These changes, although unable to affect divers' health in an immediate way, can influence their quality of life in the long term.

As regards lungs, the effects from diving are conditioned by exposure to a number of elements which are inherent in the subject's activity. Among these, we emphasize: the continuous effect of changes in pressure, the use of diving apparatus with the different breathing mixtures, the surface tasks, the years of professional activity, the maximum depth reached, and the presence of diving accidents that required recompressive treatment. On the other hand, there exist other factors, which we call accessory. They are not exclusively referred to divers, though can accelerate or retard lung disease. These factors are smoking and sports practice.

The stay in hyperabic environments consists of two phases: one of compression, involving solution of the inert gases that form the gaseous mixtures into the various organic tissues, according to Henry's law, and a posterior phase of decompression during which the dissolved gases change back into the gaseous state, being eliminated by respiration. In order to prevent inert gas bubbles from being formed during decompression, the return to surface is made following decompression tables. Occassionally, despite decompression being carried out adequately, inert gas microbubbles are formed. On their vascular itinerary, these microbubbles shall be caught, filtered and eliminated by the pulmonary alveocapillary system (10), or shall cause a transitory sensation of breathing difficulty due to a state of restrictive respiratory insufficiency (8).

The use of either open, semiclosed or closed circuit divng apparatus provides a number of benefits such as the possibility of performing prolonged immersions, at higher depths, and of using gaseous mixtures different to atmospheric air (pure oxygen, heliox or nitrox). However, diving equipment also imposes several restrictions on the respiratory system, namely:

-Increase in breathing work, owing to: a rise in the density of the breathing mixtures, as well as to a reduction in lung volume and to an increase in the dead space. All these factors will determine a type of respiration in which tidal volume is increased and frequency diminished.

- Inversion in the respiratory pattern, because of the resistance imposed by the regulator that determines that expiration plays a predominant role over inspiration. This implies greater fatigue both for the expiratory and the inspiratory musculatures (13).

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- Toxic effect of certain gases such as oxygen as it is breathed at high partial pressures, either acutely or chronically.

- Modifications to pulmonary capacities and volumes: During immersions, a decrease in vital capacity, as well as in expiratory reserve volume and in residual volume takes place. (13) Increase in static lung volumes, attributed to the breathing of dense gases (1,19) and a decrease in dynamic volumes after immersions. (4,18,21)

The whole activity of divers is not carried out underwater: an important part of their assignments consists of other surface tasks which are not exempt from danger as far as respiratory system is concerned. Among them, we emphasize: welding activities, involving inhalation of toxic fumes and gases, and the stay in confined environments where different pollutants can accumulate.

The aim of this study was to check, through the performance of spirometric techniques, the pulmonary function and the mechanism of respiratory adaptation of a group of military divers whose principal characteristic is being aged over 40. For this purpose, we considered the possible influence of a number of factors on the respiratory system. These factors are the beginning of diving activity, the maximum depth reached, smoking, sports practice, and the presence of diving accidents.

MATERIAL AND METHODS

For this study, we worked with a sample of 23 male professional military divers, appointed at the CENTRO DE BUCEO DE LA ARMADA.

Previous to the performance of the spirometry, they answered a questionnaire which collected information on general sanitary aspects and specific information on their diving activity. On the general-health section we dealt with such diverse aspects as: current sanitary state, presence of any kind of allergy (especially allergic rinitis), smoking habits and sports practice. Subsequently, we went on to assemble the data related to their professional activity: first year of diving activity, maximum depth reached and presence of any type of diving accidents that had needed recompressive treatments.

As a measure instrument we used the portable manual spirometer VITALOGRAPH COMPACT, which was calibrated daily with a 3-litre-capacity syringe, the model being 5121 and its production standard number 121, A 655 (11). The process of calibration is carried out after warming the spirometer up. Prior to the performance of the spirometry, the subject is instructed in the methodology of the research, being informed about the ventilatory movements to be made, following SEPAR´s recommendations at every moment (15).

The spirometric variables studied were: FVC, FEV1, FEV1 / FVC, FEF 25-75, FEF 75-85. The independent variables used were: smoking, sports practice, years of diving experience, maximum depth reached and the presence of any diving accidents during their professional activity.

The statistical analysis was performed emplying Student´s t test for nonparametric samples, and using quantitative and qualitative variables. We considered as significant a value $p < 0,05$.

RESULTS

Previous to the detailed study of the different groups, established according to the variables studied, we shall expound the mean results and typical deviation of age, height and spirometric parameters of the 23 divers who took part in the study (table 1):

Subsequently, we expound the results according to the characteristics considered when preparing the study of this population:

1) Smoking habits:

In this group, all those individuals who had this habit at the time of the study, and those who stated having given it up for that last year, were considered smokers. Out of the 23 divers, 8 of them were smokers (34.78%) and 15 were nonsmokers (65.22%). The average values of each parameter are on table 2

2) Sports:

The results obtained show that 11 divers (47.82%) practise sports regularly (in this case aerobic exercises), jogging being the most practised one. On the contrary, the number of divers who don´t do any activity amounts to 12 (52.17%). Both groups´spirometric results can be observed on the table 3.

3) Beginning of their professional diving occupation:

We can find two groups: those with less than 20 years of professional activity (8 divers: 34.78%) as opposed to 15 (65.22%) with more than 20 years of diving experience. The results can be observed on the Table 4.

4) Maximum depth reached:

7 divers (30.43%) belonging to this group reached a depth equal or higher than 100 metres, whereas the remaining 16 (65.27%) did not surpass this depth (table 5).

5) Presence of diving accidents which required some kind of recompressive treatment: In this last group we find that 13 divers (56.52%) had some time needed some type of recompressive treatment, while the other 10 (43.48%) had not ever suffered any diving accident during their professional activity (table 6).

DISCUSSION.

As a conclusion from the data obtained, we can state that generally, divers present larger pulmonary volumes than expected for common population. This means that these subjects can voluntarily move big amounts of gas by each ventilatory movement. According to CALDER (2), this fact is due to hypertrophy of the respiratory muscles, as well as to an increase in the alveolar size. On the contrary, other authors such as THORSEN (20) and ELLIOT (10), consider the increase in lung capacities transitory. A more remarkable decrease in this parameter shall then take place, they affirm, when the diving subject has ceased professional activity.

Similarly, we observe that these individuals show less spirometric flows than expected. It can be due to obstructive changes in small airways, as a consequence of alveolar hypertrophy that is not accompanied by any increase in the diameter of the small airways (6). This hypertrophy can be caused by the combined action of diving practice and other accessory factors like smoking and inhalation of toxic substances and pollutants. ELLIOT (9) points out that the origin of such changes is the accumulative effect of high doses of oxygen when breathing at pressures higher than 0.3 bar.

Diverse studies have attemted to demonstrate the effect of smoking on divers' pulmonary function. CIMSIT (5) revealed that there existed no significant relation between smoking and lung function in divers. Subsequently, DEMBERT (6) established that smoking caused a remarkable decrease in such parameters as FEV1 and midexpiratory flows. In our study, no relevant differences between smokers and nonsmokers show. However, we do observe how all spirometric parameters are higher in nonsmoking subjects than in smokers.

Irrespective of these results, smoking has various effects on pulmonary function which, added up to the effects of diving, make the professional activity of these subjects potentially dangerous:

a) Reduction in FEV1:

Whereas the normal decrease in this parameter is some 30 ml. per year (14), in smokers, the rate of decrease is increased because of their functional deterioration. In this way, decrease over 50 ml. per year in this parameter has led to think of a development of a chronic limitation on airflow (17).

b) Bronchial hyperreactivity:

This condition occurs in 32% of the smokers and in 21% of the ex-smokers, with a higher risk if associated with a decrease in FEV1 (13). The importance of this factor is stressed in TETZLAFF's studies (18), and he establishes that an increase in airway reactivity with no specific cause is found in divers who bear a continuous exposure to diving. This situation of bronchial hyperreactivity, associated with a greater resistance of the airway during diving, increases the risk of air trapping and the possibility of the appearance of EAG (3).

c) Difficulty in the performance of physical exercises, owing to different factors: a rise in the intrabronchial resistance, which can even be 3 times higher than normal, being located in airways smaller than 2 mm. in diameter (12); difficulty in the gaseous exchange; and an increase in blood levels of CO2. Some authors like ELLIOT (10) affirm the existence of divers who tend to retain greater amounts of CO2, due to an inadequate ventilatory response. This circumstance does not cause negative effects in the long term, but acute hypercapnia can favour the appearance of neurotoxicity or appearance of DCI.

The limitation on airflow imposed by diving equipment is added to this situation of limitated physical activity of smokers. This shall complicate still further the performance of physically-demanding tasks to these individuals.

d) According to what DEMBERT (6) points out, there exists a relationship between smoking and the greater incidence of decompressive pathology.

As regards sports practice, we observe that the differences between sportsmen and nonsportsmen are not statistically significant. However, we find it necessary to comment that all spirometric parameters are higher in the sporting group than in the nonsporting. We recommend doing aerobic physical exercise in a progressive way and suitably according to age, as the use of diving apparatus requires greater effort from the respiratpry musculature. Divers must deal with this aspect in order to carry out a safe underwater activity.

The principal effects of physical activity upon respiratory system, from the point of view of underwater activity, are: decrease in respiratory work, given the improvement in the elasticity of pulmonary parenchyma, in proportion to the decrease in the resistance to airflow, as well as an increase in lung volumes and capacities which is to favour the process of pulmonary diffusion (12).

The beginning of diving activity is significantly modified in those parameters that show expiratory flows. This way, whereas the relation between FEV1 / FVC% ($p< 0.005$) and FEF 25-75% ($p<0.02$) stands out, other flow parameters such as FVC are not affected in a significant way. However, parameters like FVC show higher values, though not significant, in divers with over 20 years of professional activity. These results appear to indicate that, while pulmonary volumes stay the same or even increase in time, there takes place a situation compatible with an obstruction in small airways in divers with more professional experience. (1,16) Such other authors like DENISON (7) believe that decrease in those expiratory flows is not caused by an obstructive pathology, but by a lower distensibility and a higher tendency to collapse of the airway. THORSEN (19) establishes that one of the long-term effects of diving upon lungs is a decrease in elasticity of small airways.

Concerning maximum depth reached, we notice a significant change in all parameters that indicate obstructive situations of airways of different sizes Authors like THORSEN (19) consider that changes in lung function of divers who reach high depths are permanent and that it does not turn to normal once the diver has ceased professional activity.

An aspect which does not significantly influence on the diverse spirometric parameters studied is the presence or absence of diving accidents during divers´professional activity. In this way, it should appear logical to think that those individuals who undergo hyperabic treatment and therefore take high doses of oxygen for prolonged periods are to possess a more affected lung function.

As a conclusion to our study, we observe that divers aged over 40 years old show larger lung capacities than normal population, whereas parameters which indicate airway obstruction are decreased. This fact leads to consider the presence of an asymptomatic obstruction of small airways. Other parameters studied such as smoking and sports practice do not influence on these divers´pulmonary function, while two factors like the number of years of diving activity and maximum depth reached do significantly influence upon lung function in this group of divers.

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TABLE 1.- Age, Height and spirometric parameters (Mean value)

PARAMETER	VALUE	D.S.
AGE	44.21	3.19
HEIGHT	174.26	5.97
FVC	4.78	0.69
FVC %	104.87	11.66
FEV1	3.69	0.52
FEV1%	98.60	12.35
FEV1 / FVC%	77.52	4.43
FEF 25-75%	90.87	24.69
FEF 75 -85%	82.65	32.59

TABLE 2. Smokings habits (Mean Value)

Parameter	Smoker	D.S.	Nonsmoker	D.S.	PValue
FVC%	100.00	11.23	107.46	11.39	0.14
FEV1 %	95.37	9.53	100.33	13.61	0.37
FEV1 / FVC%	78.62	3.73	76.93	4.77	0.39
FEF 25-75%	88.75	17.23	92.00	28.38	0.77
FEF 75-85%	79.75	21.55	84.20	37.81	0.76

TABLE 3.-Sports Habits (Mean Values)

Parameter	No Sport	D.S.	Sport	D.S.	P Value
FVC%	101.75	12.27	108.27	10.44	0.18
FEV1 %	95.33	11.69	102.18	12.58	0.19
FEV1 / FVC%	77.50	4.07	77.54	4.98	0.98
FEF 25-75%	85.00	19.33	97.27	29.03	0.24
FEF 75-85%	73.83	22.63	92.27	39.73	0.18

TABLE 4.- Beginning of their professional diving activities (MeanValue)

Parameter	< 20 years	D.S.	> 20 years	D.S.	P Value
FVC%	104.62	8.53	105.00	13.31	0.94
FEV1 %	102.12	12.57	96.73	12.24	0.33
FEV1 / FVC%	80.87	4.12	75.73	3.53	0.005
FEF 25-75%	106.62	27.99	82.46	18.67	0.02
FEF 75-85%	98.00	42.94	74.46	23.25	0.10

TABLE 5.- Maximum depth (Mean Value)

Parameter	<100meters	D.S.	>100 meters	D.S.	Pvalue
FVC%	106.50	11.48	101.14	12.06	0.32
FEV1 %	101.81	11.39	91.28	12.05	0.05
FEV1 / FVC%	79.06	4.34	74.00	2.00	0.008
FEF 25-75%	99.75	21.91	70.57	18.54	0.006
FEF 75-85%	91.06	32.85	63.42	24.03	0.05

TABLE 6.- DIVING ACCIDENT (Mean Value)

Parameter	No accident	D.S.	Accident	D.S.	P Value
FVC%	107.27	12.72	102.66	10.67	0.35
FEV1 %	98.63	11.76	98.58	13.39	0.99
FEV1 / FVC%	75.81	3.89	79.08	4.46	0.07
FEF 25-75%	83.27	17.14	97.83	29.00	0.16
FEF 75-85%	76.63	20.66	88.16	40.83	0.4

LE SOMMEIL ET L'AGE : DE LA PHYSIOPATHOLOGIE A LA THERAPEUTIQUE

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• RESUME

Introduction : Les rythmes circadiens et tout particulièrement le rythme veille/sommeil ont été étudiés par des méthodes paracliniques (EEG, MSLT, actimétrie) et biochimiques (taux de mélatonine) ainsi que par des tests neuro-psychologiques évaluant le retentissement des troubles du sommeil. Ces investigations ont permis de montrer des modifications significatives du sommeil dès 35 ans.

Le propos de cet article est de faire le point sur les connaissances actuelles de l'influence de l'âge sur le sommeil et sur les possibilités thérapeutiques de récupération d'un sommeil satisfaisant ou de maintien de l'éveil, en situations opérationnelles militaires.

Physiologie : Les principales altérations apparaissant à partir de 35 ans sont une réduction de l'amplitude des rythmes circadiens, une avance de phase et un raccourcissement de période des rythmes de la température, de la mélatonine et du cycle veille/sommeil, une augmentation de la latence d'endormissement et du sommeil léger (stades 1 et 2), une diminution du sommeil lent profond (stades 3 et 4) et du sommeil paradoxal ainsi qu'une fragmentation du sommeil. Ces phénomènes peuvent être expliqués principalement par une réduction de la sensibilité de la rétine à la lumière et par des changements morphologiques et chimiques du noyau suprachiasmatique et de la glande pinéale (diminution de la sécrétion de mélatonine). Il en résulte une mauvaise qualité de sommeil affectant les performances et l'humeur du sujet.

Thérapeutique : Des méthodes non pharmacologiques pourraient améliorer la qualité du sommeil. Les plus connues sont le maintien d'une organisation circadienne stricte de l'éveil et du sommeil (veille stimulante, lever à heure fixe...), la pratique de petits sommes qui permettent une meilleure tolérance à la privation de sommeil (usage sportif et militaire essentiellement), la stimulation photonique qui avance la phase de sécrétion nocturne de mélatonine et optimise ainsi son action hypnotique.

Un certain nombre de substances pharmacologiques peuvent également être utilisées. Elles se répartissent en deux classes : les hypnotiques et les psychostimulants. Les hypnotiques de type benzodiazépine permettent d'induire le sommeil mais présentent de nombreux effets secondaires (somnolence, fatigue diurne, diminution des performances psychomotrices) et tendent donc à être remplacés par des molécules de type non benzodiazépine, telles que les dérivés de la cyclopyrrolone et de l'imidazopyridine dépourvus d'effets résiduels diurnes. De plus, la mélatonine exogène, jouant sur l'apparition des phases du sommeil et sur la température centrale, pourrait compenser les troubles du rythme circadien apparaissant avec l'âge.

D'autre part, l'utilisation de psychostimulants pourrait permettre de diminuer les perturbations diurnes liées à une mauvaise qualité de sommeil. Le modafinil, dont les indications thérapeutiques sont la narcolepsie et l'hypersomnie idiopathique, est capable d'améliorer les performances préalablement dégradées du sujet. La caféine LP, actuellement à l'étude, possède aussi des propriétés éveillantes bénéfiques, démontrées en condition de jet-lag et en situation de privation de sommeil.

Conclusion : Les importantes modifications des caractéristiques du sommeil avec l'âge entraînent une diminution de son rôle restaurateur et une baisse de la vigilance diurne, ces deux conséquences étant pénalisantes en conditions opérationnelles. Le choix parmi les hypnotiques de nouvelle génération et les psychostimulants permet désormais de corriger de manière sûre et optimale ces troubles circadiens et d'assurer la fiabilité de toute opération militaire.

1• LE VIEILLISSEMENT

Selon le "Robert", c'est la période de la vie qui suit l'âge mûr" et qui est caractérisée par une "détérioration fonctionnelle progressive associée à une diminution des capacités d'adaptation et de réponse aux stress de l'environnement" (Vander *et al.*, 1989). Il s'agit d'un processus physiologique normal, résultant du remplacement progressif des éléments nobles des organes par du tissu conjonctif (sclérose).

Au niveau de l'approche chronobiologique du vieillissement, les rythmes biologiques sont des phénomènes adaptatifs aux variations périodiques de l'environnement (alternance lumière-obscurité, variations de température,...). Le vieillissement peut être considéré comme une perte de la structure temporelle, à cause en partie de la perturbation des rythmes biologiques.

Le vieillissement est un processus irréversible qui débute en fait dès la naissance. Plus couramment, certains auteurs considèrent que les modifications physiologiques deviennent mesurables à partir de l'âge de 40 ans. L'étude de ces modifications et de leurs conséquences est ainsi pleinement justifiée dans le cadre militaire dans lequel le niveau de performance doit rester constant pendant toute la durée de la carrière, et ceci en dépit des nombreuses perturbations du rythme veille-sommeil imposées par l'activité militaire : privation de sommeil, jet-lag, déploiement de troupes,....

Le propos de cet article est de faire le point sur les connaissances actuelles de l'influence de l'âge sur le

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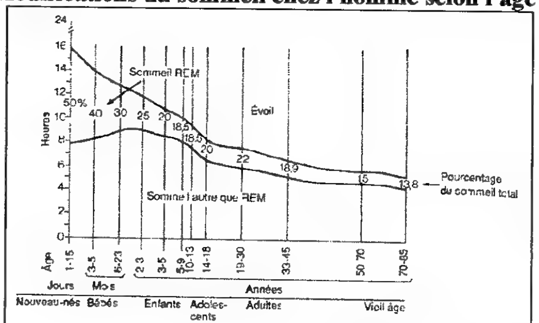
sommeil et sur les possibilités thérapeutiques de récupération d'un sommeil satisfaisant ou de maintien de l'éveil, en situations opérationnelles militaires.

2• EVOLUTION DU SOMMEIL ET DES RYTHMES CIRCADIENS AVEC L'AGE

Avec l'âge, de nombreux paramètres du sommeil se modifient, tant sur le plan qualitatif que quantitatif (Scott & Bundlie, 1998 ; Webb, 1982 ; Webb *et al.*, 1984 ; Webb, 1989) et ceci dès l'âge de 35 ans comme l'ont montré Blois *et al.* en 1983 et Boselli *et al.* en 1998 :

PARAMETRE	VARIATION
Latence d'endormissement	↗
Heure de réveil	survient plus tôt
Sommeil efficace	↘
Temps de sommeil nocturne	↘
Pourcentage de stade 1	↗
Pourcentage de stade 2	↗
Pourcentage de stade 3	↘
Pourcentage de stade 4	↘
Pourcentage de sommeil lent	↘
Pourcentage de sommeil paradoxal	≈, morcelé
Micro-éveils	↗
Somnolence diurne	↗
Insomnies	↗
Amplitude des rythmes circadiens	↘
Amplitude du cycle veille-sommeil	↘

Modifications du sommeil chez l'homme selon l'âge :



(d'après Roffwarg et al., 1966))

- Diminution du temps de sommeil nocturne

Le sujet âgé perd son pouvoir de récupération, la durée de son sommeil n'est plus modulable.

- Altération de la continuité du sommeil

Cette idée est justifiée par les nombreux changements dans les stades, ainsi que par l'augmentation du nombre et de la durée des éveils nocturnes (par diminution du seuil d'éveil).

- Architecture du sommeil

Les deux types de sommeil, sommeil lent et sommeil paradoxal, ne sont pas altérés de la même façon par le processus de vieillissement. Le sommeil lent profond est précocement touché : ainsi le pourcentage de stade 4 diminue dès 40 ans pour quasiment disparaître après 70 ans (expliquant l'amenuisement des capacités de récupération avec l'âge), le pourcentage de stade 3 diminue également, au profit de l'augmentation des stades 1 et 2.
Le sommeil paradoxal ne diminue qu'à un âge très avancé, simultanément à la perte des possibilités intellectuelles. Auparavant, celui-ci est instable et morcelé, fragmenté par des épisodes de sommeil lent léger ou de veille, mais toujours présent.

- Le rythme veille-sommeil

Il se désorganise progressivement à cause des éveils nocturnes, et des épisodes de somnolence diurne. La durée de sommeil reste constante sur 24 heures, mais le maintien de l'état de veille devient de plus en plus difficile.

- Causes et mécanismes

Le rythme veille-sommeil est régulé par des pace-makers subcorticaux thalamiques. La diminution des amplitudes serait due à une diminution du nombre total de neurones mis en jeu d'une part et à une moindre efficacité de la réponse neuronale d'autre part.

3• VIEILLISSEMENT ET PRIVATION DE SOMMEIL

- Symptômes de la privation de sommeil

Elle entraîne une fatigue persistante, qui diffère de celle créée par un effort physique ou mental. Il en découle une irritabilité, des sensations de malaises et d'épuisement, conduisant à une baisse sensible de l'attention et de la vigilance, puis des performances. La vigilance diminue entre la cinquième et la dixième heure de privation de sommeil, puis après la quinzième heure (Giam, 1997).

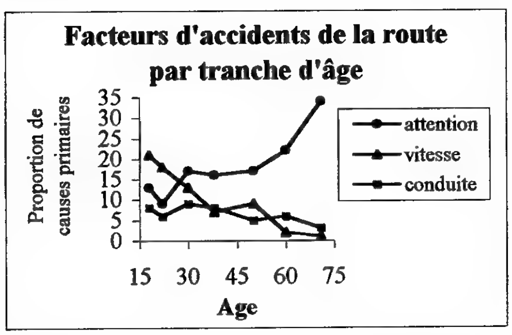
- Effets de l'âge sur l'adaptation et la récupération à une privation de sommeil

Le manque de sommeil devient de plus en plus pénalisant avec l'âge. Oginska a montré en 1993 un effet significatif de l'âge sur la fréquence de survenue de fatigue chronique après privation de sommeil. L'âge critique se situe, selon lui, entre 40 et 50 ans. Au delà, des troubles tels qu'une difficulté à s'endormir, des micro-éveils fréquents, un réveil précoce apparaissent. Ils semblent affecter de manière plus importante les femmes que les hommes. Une étude de Webb en 1989 sur deux jours de privation de sommeil, montre que les sujets âgés sont plus affectés par la privation, non seulement au niveau des mesures de persistance de l'attention et des estimations subjectives de somnolence, mais aussi au niveau d'un test de travail intellectuel. Pour Horne (1988) il semble que la somnolence débute plus tôt pour les sujets âgés, notamment dès la fin de la première nuit de perte de sommeil et que la fréquence de napping augmente avec l'âge.
De plus, il existe des différences interindividuelles selon le caractère "du matin" ou "du soir" ; ceux du matin supportant moins bien le travail posté. Avec l'âge, les sujets se considèrent plus adaptés au travail du matin qu'au travail de nuit. Gander (1993) émet alors l'hypothèse que les sujets deviendraient plutôt du matin en vieillissant.
Dans ce cas précis, deux grandes modifications peuvent expliquer la perte progressive des capacités de récupération après une privation de sommeil avec l'âge (Reilly *et al.*, 1997) : il s'agit d'une diminution de

l'amplitude du cycle veille-sommeil et d'une diminution de l'amplitude des rythmes circadiens (principalement celui de la température corporelle) (Van Reeth, 1998 ; Gander *et al.*, 1993 ; Harma *et al.*, 1994).
Les modifications physiologiques liées à l'âge sont développées dans un chapitre ultérieur.

4• JET-LAG
Le syndrôme de désynchronisation lié au décalage horaire induit un état de dyschronisme entre l'horloge biologique (désynchronisation externe) et les rythmes biologiques (désynchronisation interne). Malgré le peu d'études des effets de l'âge sur le jet-lag, il semblerait qu'un tempérament du soir et un âge jeune soient en faveur d'un rétablissement rapide (Benoît, 1996 ; Gander *et al.*, 1993). Les résultats d'une étude récente menée par notre équipe (Lagarde *et al.*, publication soumise), et présentée dans un autre papier à ce symposium, montre que l'âge n'a pas d'influence sur les performances physiques ainsi que sur l'attention, mais que les sujets de plus de 35 ans se sentent mieux que les jeunes (évaluation au moyen des Echelles Visuelles Analogiques). Les vétérans, peut-être en raison de leur expérience, ne semblent pas être réellement pénalisés dans le cadre d'un déploiement opérationnel réel de troupes.

5• CONSEQUENCES EN ACCIDENTOLOGIE
La fatigue et la perte de sommeil sont des facteurs importants impliqués dans les incidents et les accidents dans les transports, notamment sur route (Aldrich, 1989). L'inattention devient rapidement la cause principale d'accidents, dès la tranche 45-60 ans (Summala & Mikkola, 1994). Ceux-ci se produisent surtout en milieu d'après-midi pour ces sujets:



La vigilance semble être influencée de façon négative par le vieillissement, et peut devenir responsable d'accidents du travail, d'erreurs de jugement dans les professions à responsabilité..., à l'origine de coûts très importants pour la société (Leger, 1994).
Toutefois, un âge mûr peut aussi parfois contrebalancer les effets néfastes du vieillissement : les mauvaises habitudes de sommeil des sujets jeunes, surestimant leurs capacités de récupération, conduisent à des privations de sommeil aux conséquences dangereuses (Philip *et al.*, 1999).

6• MODIFICATIONS PHYSIOLOGIQUES RESPONSABLES D'UNE MAUVAISE QUALITE DE SOMMEIL
La mélatonine, produite dans la glande pinéale, présente un rythme circadien avec un pic de sécrétion vers 2 heures. Elle a comme rôle essentiel d'être un médiateur de l'information qui apporte à l'organisme la notion de durée de l'obscurité ; elle est responsable de la synchronisation de diverses fonctions rythmiques de l'organisme. Sa production atteint un maximum vers l'âge de 3-5 ans puis diminue progressivement avec l'âge. Ses concentrations diurne et nocturne au niveau du liquide cérébro-spinal baissent avec le vieillissement (Iguchi *et al.*, 1982 ; Waldhauser *et al.*, 1998).
Les mécanismes impliqués dans cette réduction sont encore peu connus. Cependant quelques hypothèses peuvent être retenues (Myers & Badia, 1995) :
- une calcification de la glande pinéale,
- un métabolisme plus intense ou une clairance majorée de l'hormone,
- des changements dans les afférences et efférences neuronales et dans les connections chimiques avec le noyau suprachiasmatique,
- des changements d'expression génétique dans le noyau suprachiasmatique et/ou la glande pinéale,
- une réduction de la sensibilité de la rétine à la lumière,
- des réductions dans la durée d'exposition à la lumière vive.

La mélatonine ayant un double rôle hypnotique et synchronisateur, sa diminution progressive a pour conséquences (Van Cauter *et al.*, 1998 ; Myers & Badia, 1995 ; Gander *et al.*, 1993) :

- une atténuation des amplitudes circadiennes
Ce sont les changements les plus constants observés avec l'âge. Ils concernent le rythme de la température corporelle et le rythme veille-sommeil (Campbell & Murphy, 1998). Les troubles qui en résultent sont principalement une réduction du sommeil nocturne et une baisse de la vigilance et de la performance intellectuelle.

- une avance de phase circadienne
Elle concerne la mélatonine, la température et le rythme veille-sommeil. Les sujets âgés vont plus tôt au lit que les sujets jeunes, à cause d'une phase plus précoce du rythme de la température. Une désynchronisation des différents rythmes peut également apparaître avec l'âge (Czeisler *et al.*, 1999 ; Moore, 1999).

- un raccourcissement de période
Il apparaît de manière inconstante mais semble bien exister.

En conclusion, le vieillissement est caractérisé notamment par des changements dans le système circadien. Depuis que l'on connaît les conséquences de ces modifications avec l'âge, particulièrement sur la qualité et la quantité de sommeil, la vigilance et les performances, la nécessité de trouver des traitements afin

de rétablir au mieux l'ensemble de ces paramètres semble évidente.

7• MESURES PERMETTANT DE REDUIRE LES EFFETS DU VIEILLISSEMENT SUR LES PERTURBATIONS DU RYTHME VEILLE-SOMMEIL.

- Méthodes non pharmacologiques

- L'approche comportementale

Le système hypnique du sujet âgé possède un rendement médiocre, et le sujet tend à passer de plus en plus de temps au lit sans pour autant améliorer la durée et la qualité de son sommeil. La technique de restriction du temps passé au lit permet de lutter contre les insomnies : l'augmentation progressive de la durée de veille améliore la continuité et la profondeur du sommeil nocturne.

- L'hygiène du sommeil

Le sommeil étant sensible à toute modification comportementale, il importe de maintenir une organisation circadienne stricte, d'avoir une veille stimulante, de ne pas faire d'exercice physique ou intellectuel avant le coucher et de se réveiller à heure fixe. Pour résumer, il convient de rechercher plutôt un sommeil bien organisé et continu qu'un sommeil prolongé.

- La pratique de petits sommes

Cette technique est surtout utilisée en milieu sportif et militaire pour permettre une meilleure tolérance à la privation de sommeil. Elle consiste à faire de courtes périodes de sommeil. Un "nap" de courte durée avant une veille prolongée, pour un sujet sans dette de sommeil, permet de maintenir performance et vigilance plus longtemps (Dinges & Broughton, 1989). Cependant cette méthode a ses limites car la récupération après un certain nombre de "naps" consécutifs devient moins efficace.

- La stimulation photique

Le but de cette technique est d'inhiber la sécrétion de mélatonine endogène pendant la journée, pour permettre une condensation de la période de production (Myers & Badia, 1995). Ainsi le pic nocturne redevient important : l'augmentation de l'amplitude circadienne permet d'affecter tous les systèmes cibles et d'induire leur resynchronisation.

Cette méthode n'est pas très répandue, car elle est seulement efficace chez les jeunes et les personnes très âgées (donc hors du contexte militaire). De plus, ses effets à long terme ne sont pas encore connus.

- L'exercice physique

Il semble intéressant de pratiquer un exercice physique intense nocturne pendant une période de travail posté, ce qui fait décroître la fatigue et les symptômes musculosquelettiques (Van Reeth, 1998).

- Méthodes pharmacologiques

(Lagarde, 1991)

- La mélatonine exogène

Des effets hypothermiques et hypnotiques significatifs sont dus à la mélatonine (Reid *et al.*, 1996). La diminution de la température corporelle nocturne est associée à une augmentation des proportions veille-sommeil et de la qualité du sommeil (Weitzmen *et al.*, 1982). Par conséquent, les effets hypnotiques de la mélatonine pourraient être provoqués par l'abaissement de la température centrale (Reid *et al.*, 1996).

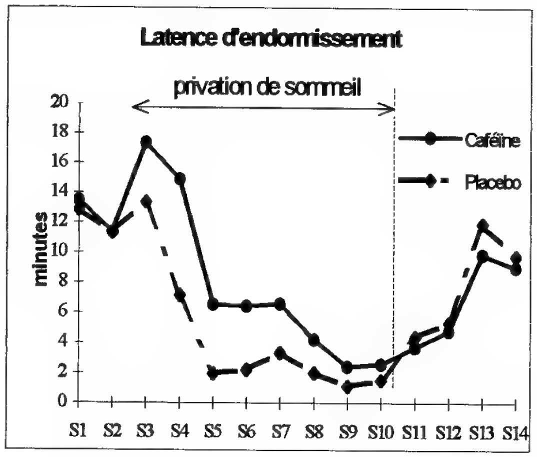
L'administration de mélatonine exogène provoque la réduction des moyennes des latences des stades 1 et 2 de 40% et 25% respectivement (Reid *et al.*, 1996).

- La caféine à libération prolongée (STINERGIC®)

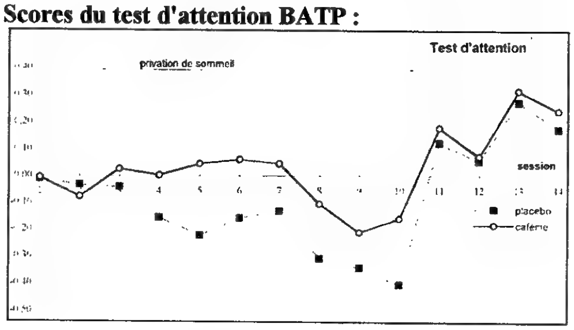
Son étude a déjà fait l'objet de plusieurs communications dans les précédentes réunions organisées sous l'égide de l'OTAN (RTO). Pour résumer, elle possède un effet éveillant, et augmente les niveaux de vigilance et de performances lorsque ceux-ci sont préalablement dégradés.

Dans le cadre d'une privation de sommeil, elle augmente la latence d'endormissement et améliore les scores d'un test d'attention (Lagarde *et al.*, 1996) :

Latence d'endormissement selon la session :



Scores du test d'attention BATP :



- Le modafinil (MODIODAL®, PROVIGIL®)

Le modafinil est une molécule récente qui permet de stimuler la vigilance. Son mode d'action semble lié à la

potentialisation de l'activité α_1 adrénergique au niveau cérébral, sans effet de type amphétaminique (absence de modification des paramètres cardiovasculaires, du comportement, de l'appétit, pas d'accoutumance). C'est un médicament qui, selon la dose administrée, restaure ou augmente les niveaux d'éveil et de vigilance diurne.
Lors d'une privation de sommeil, il permet de supprimer les épisodes de micro-sommeil (Lagarde & Batejat, 1995 ; Lagarde, 1995).
Il est indiqué dans la narcolepsie avec ou sans cataplexie et les hypersomnies idiopathiques, et a déjà été utilisé en milieu militaire au cours de la guerre du Golfe et s'est avéré utile chez les militaires senior. Il a déjà fait l'objet de présentations dans le cadre de l'OTAN.
Actuellement, aucune étude ne relate l'intérêt du modafinil dans le traitement des effets du vieillissement sur le sommeil. Toutefois il est possible de supposer qu'en favorisant l'état de veille pendant la journée avec l'administration matinale de modafinil, il soit possible d'améliorer le sommeil, comme cela est réalisé en pathologie dans le cadre des insomnies nocturnes (Garma *et al.*, 1987).

- Les hypnotiques de type benzodiazépine

Ils induisent le sommeil par action plus ou moins marquée sur les récepteurs au GABA. Leurs effets sur l'architecture du sommeil sont résumés dans le tableau suivant :

PARAMETRE	VARIATION
Latence d'endormissement	↘
Eveils nocturnes	↘
Pourcentage de stade 2	↗
Pourcentage de stades 3 et 4	↘
Pourcentage de sommeil paradoxal	↘

Ils présentent de nombreux effets secondaires tels que : somnolence diurne, fatigue, vertiges, dépression, dépendance, amnésie antérograde, rebond d'anxiété, syndrome de sevrage, ce qui tend à limiter leur emploi.

- Les hypnotiques de type non-benzodiazépine

Malgré leur structure chimique différente, ils se lient aux récepteurs du GABA mais ne présentent pas les mêmes caractéristiques.

• dérivés de la cyclopyrrolone : la zopiclone (IMOVANE®)

Ses effets sur l'architecture du sommeil sont résumés dans le tableau suivant :

PARAMETRE	VARIATION
Eveils nocturnes	↘
Pourcentage de stade 2	↗
Pourcentage de stades 3 et 4	↗
Sommeil paradoxal	retardé

Aucune diminution des performances diurnes n'a été rapportée.

• dérivés de l'imidazopyridine : le zolpidem (STILNOX®, AMBIEN®)

C'est le produit qui se rapproche le plus de l'hypnotique idéal :

PARAMETRE	VARIATION
Pourcentage de stades 1 et 2	↗
Sommeil paradoxal	retardé

Il ne provoque pas d'insomnie de rebond à l'arrêt du traitement ni de diminution des performances diurnes.
Il pourrait ainsi être utilisable de manière sûre en situation militaire (Sicard, 1993).

8• CONCLUSION

Les importantes modifications des caractéristiques du sommeil avec l'âge entraînent dès 45 ans une diminution de son rôle restaurateur (par modification de l'architecture du sommeil) et une baisse de la vigilance diurne. Ces modifications s'expliquent en physiologie et en pathologie par un changement dans la sécrétion endocrinienne, notamment de mélatonine. Des mesures physiologiques ou pharmacologiques peuvent être conseillées : le choix parmi les hypnotiques de nouvelle génération et les psychostimulants permet désormais de corriger de manière sûre et optimale ces troubles circadiens. Ces mesures doivent ainsi permettre aux militaires entre 40 et 60 ans de maintenir une vigilance et donc une performance compatible à l'accomplissement des missions qui leur sont confiées.

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SLEEP AND AGE : FROM PHYSIOPATHOLOGY TO THERAPEUTICS

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• ABSTRACT

Introduction : Circadian rhythms and especially light/dark cycle have been studied using paraclinical (EEG, MSLT, actimetry) and biochemical (melatonin level) methods and neuropsychological tests which evaluate sleep disorders effects. These investigations allow to point out significant changes in sleep as soon as 35 years old.

The purpose of this paper is to sum up current knowledge of age influence on sleep and therapeutic ways of good sleep quality recovery or wakefulness preservation, in military operational condition.

Physiology : Main deteriorations which occur from 35 are a decrease in circadian rhythms amplitude, a phase advance and a period shortening of temperature, melatonin and light/dark cycle rhythms, an increase in sleep onset latency and stades 1 and 2, a decrease in SWS (stades 3 and 4) and REM as a sleep fragmentation (increase of WASO). These phenomena could be mainly explained by reduction of retina sensivity to light and by morphological and chemical changes of suprachiasmatic nuclei and epiphysis (decrease in melatonin secretion). The resulting altered quality of sleep affects performances and mood of subjects.

Therapeutics : Non-pharmacological methods could improve quality of sleep. The best methods are a strict respect of light/dark cycle (stimulating waking, awakening at set time...), napping which allows a best tolerance of sleep deprivation (for use of sportsmen and servicemen basically), the photonic stimulation which advances night secretion phase of melatonin and so improves its hypnotic power.

Some pharmacological coumpounds may also be used. They can be divided into two sets : hypnotics and psychostimulants. Hypnotics like benzodiazepines induce sleep but have got many side effects (sleepiness, diurnal tiredness, physical performances decrease) and tend to be replaced by non-benzodiazepine molecules such as cyclopyrrolone and imidazopyridine derivatives lacking diurnal residual effects.

Moreover, exogenous melatonine, acting on sleeping phases apparition and on central temperature, may compensate circadian rhythms troubles which appear with aging.

On the other hand, psychostimulants could reduce diurnal disorders due to a bad sleep quality. Modafinil, suitable for narcolepsy and idiopathic hypersomnia, can improve previously altered performances. Slow release caffeine, which is currently studied, possesses some beneficial wakening properties demonstrated in jet-lag and sleep deprivation conditions.

Conclusion : Important changes of sleep parameters with aging trigger a decrease in its recovery properties and a reduction of diurnal vigilance, these two consequences being deleterious in operational condition. Now, the choice between psychostimulants and new hypnotics could correct these circadian troubles, without side effects and efficiently, and could ensure reliability in every military condition.

1• AGING

According to the "Robert & Collins" dictionnary, aging corresponds to the period of life which follows middle age, and which is characterized by a gradual fonctional damaging associated to a decrease in adaptability and response capacity to environmental stressors. (Vander *et al.*, 1989). This physiological decrease is normal, resulting from the gradual replacement of noble organ's elements by conjunctive tissue (sclerosis).

With a chronobiological approach of aging, biological rhythms are adaptable to environmental periodic variations (day-night cycle, temperature variations,..). Aging may be considered as a loss of time structure, because of disturbancies of biological rhythms.

Aging is an irreversible phenomenon which begins immediately after the birth. In the litterature, some authors consider that physiological modifications become measurable from 40 years old on. Study of these modifications and their consequences is fully justified in a military context : the level of performance must remain steady during the whole carrier, despite of numerous disturbancies of the wake-sleep rhythm such as sleep deprivation, jet-lag, troops deployement ...

The purpose of this article is to take the position on current knowledge of the influence of aging on sleep and determine therapeutic possibilities that may be used to restore a good sleep quality and/or to maintain awakening.

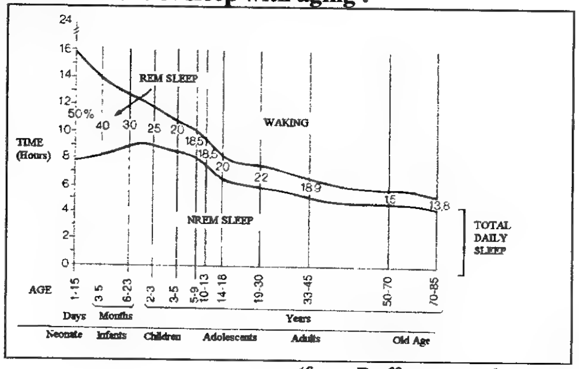
2• EVOLUTION OF SLEEP AND CIRCADIAN RHYTHMS WITH AGING

With aging, many sleep parameters are modified, in qualitative and quantitative aspects as well (Scott & Bundlie, 1998 ; Webb, 1989 ; Webb *et al.*, 1984 ; Webb, 1982) ; and it appears even the age of 35-40 years as it was demonsrated by Blois *et al.* in 1983 and Boselli *et al.* in 1998 :

Paper presented at the RTO HFM Symposium on "Operational Issues of Aging Crewmembers", held in Toulon, France, 11-14 October 1999, and published in RTO MP-33.

PARAMETER	VARIATION
Sleep onset latency	↗
Waking time	sooner
Efficient sleep	↘
Nighttime sleep	↘
Percentage of stage 1	↗
Percentage of stage 2	↗
Percentage of stage 3	↘
Percentage of stage 4	↘
Percentage of slow wave sleep	↘
Percentage of REM sleep	≈, broken up
Arousals	↗
Daylight sleepiness	↗
Insomnia	↗
Amplitude of circadian rhythms	↘
Amplitude of wake-sleep cycle	↘

Modifications of sleep with aging :



(from Roffwarg et al., 1966)

- Decrease in nighttime sleep

Elderly people loose their recovery capacities, their sleep's length is not yet modifiable.

- Impairment of sleep continuity

This idea is justified by numerous changes in the different sleep stages and an increase in number and duration of awakenings (because of a decrease in awakening threshold).

- Sleep architecture

The two types of sleep, slow wave sleep and REM sleep, are not altered on the same way with aging. Slow wave sleep is first modified : the percentage of stage 4 decreases from 40 on and disappears after 70. The percentage of stage 3 decreases too, whereas stages 1 and 2 increase.

The REM sleep decreases only in very old subjects, parallel to senile dementia. Before this period, the REM sleep is always present, but broken up with slow wave sleep or awakening episodes.

- Wake-sleep cycle

It gradually becomes disorganized because of nighttime arousals and daylight sleepiness. The total sleep time stay constant throughout 24 hours, but the maintain of awakening stages becomes more and more difficult.

- Causes and mechanisms

The wake-sleep rhythm is regulated by thalamic subcortical pace-makers. The decrease in amplitudes should be due to losses of neurones and moreover to a lower efficiency of the neuronal response.

3• SLEEP DEPRIVATION AND AGING

- Symptoms of sleep deprivation

A persistent fatigue appears, different from the one due to a physical or mental strain. It follows an irritability, faint and exhaustion feelings, resulting in a noticeable decrease in attention, vigilance and performances. The most important decreases in vigilance appear between the fifth and the tenth hour, then after the fifteenth hour of sleep deprivation (Giam, 1997).

- Effects of age on adaptation and recuperation to a sleep deprivation

The lack of sleep becomes more and more penalizing with aging. Oginska demonstrated in 1993 a significative effect of aging on chronic fatigue apparition after a sleep deprivation. According to him, the critical age is about 40-50. Beyond 50, some disturbancies begin to appear such as an increase in sleep onset latency, some arousals and a early awakening. Women are the most disturbed.
A study by Webb (1989), on two days of sleep deprivation, described not only a decrease in attention and an increase in subjective somnolence but also few deficiences in an intellectual task for elderly people. For Horne (1998), sleepiness appears sooner for elderly people, just after the first night of sleep deprivation ; the number of nappings increases with aging too.
Moreover, individual differences exists, according to the "morningness" or "eveningness" type ; "morningness" people conform themselves less to shift work. Elderly people become "morningness" type with aging (Gander, 1993).
In this case, two major modifications can explain the gradual loss of recovery capacities after a sleep deprivation with aging (Reilly *et al.*, 1997) : first a decrease in the amplitude of the wake-sleep rhythm, second a decrease in the amplitude of circadian rhythms (temperature,...) (Van Reeth, 1998 ; Gander *et al.*, 1993 ; Harma *et al.*, 1994).
General age-related modifications are related in a later paragraph.

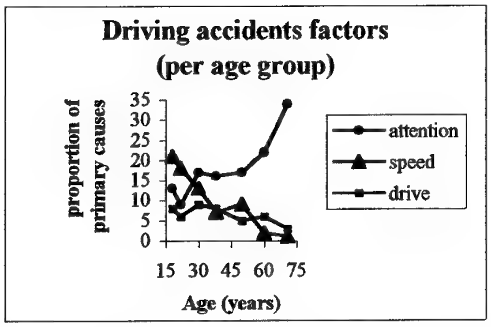
4• JET-LAG

Jet-lag syndrome induces a desynchronization between environmental synchronisors and the biological clock (external desynchronization) and between different biological rhythms with different time periods (internal desynchronization). Despite of the lack of studies about the influence of age on jet-lag syndrome, a young subject with "eveningness" type should recover health faster. (Benoît, 1996 ; Gander *et al.*, 1993).
Results from a recent study, realized in our group (Lagarde *et al.*, submitted publication) and presented in another paper at this symposium, show that physical performance and attention level are not affected by aging. Nevertheless, people over 35 feel better than young ones (scored with Visual Analogue Scales).

Veterans, perhaps because of their experience, do not seem to be penalized during a troops deployement.

5• CONSEQUENCES IN ACCIDENTOLOGY

Fatigue and sleep losses are important factors responsible for many traffic accidents (Aldrich, 1989). Lack of attention is the major factor over 30 years old (Summala & Mikkola, 1994). The most dangerous period is the beginning of the afternoon for people over 50.



Vigilance seems to be negatively influenced by aging, and may be responsible for industrial injuries, misinterpretations, misdirections..., that induces an important economic cost for the society (Leger, 1994).
Nevertheless, elderly people can compensate these negative effects with an enhanced experience. On the contrary, bad sleep hygiene of young people - with numerous sleep deprivations without any subjective effect - leads them to dangerous attitudes (Philip *et al.*, 1999).

6• PHYSIOLOGICAL MODIFICATIONS RESPONSIBLE FOR BAD SLEEP QUALITY

Melatonin, produced in the pineal gland, presents a circadian rhythm with a maximal production at 02:00. It is essentially a mediator of information about the light-darkness cycle. It synchronizes various rhythmic functions. Over 5 years old, its production decreases gradually ; daylight and nighttime concentrations in the cerebro-spinal liquid decrease with aging (Iguchi *et al.*, 1982 ; Waldhauser *et al.*, 1998).
Mechanisms responsible for these phenomena still remain unknown. Nevertheless, few explanations should be given (Myers & Badia, 1995) :
- a calcification of the pineal gland,
- a more intensive metabolism or hormone's clearance,
- some changes in neuronal afferences and efferences in the suprachiasmatic nucleus,
- some changes in the genetic expression level in the suprachiasmatic nucleus and/or the pineal gland,
- a reduction of light sensitivity of the retina and a reduced time to light exposure.

Melatonin gradual disparition results in (Van Cauter *et al.*, 1998 ; Myers & Badia, 1995 ; Gander *et al.*, 1993) :

- A decrease in circadian amplitudes

It represents the most usual changes with aging : temperature rhythm and wake-sleep rhythm are the first parameters modified (Campbell & Murphy, 1998).
These changes induce a reduction of nighttime sleep, daylight vigilance and intellectual performance

- A circadian phase advance

It affects melatonin, temperature and wake-sleep rhythms. Elderly people are going earlier to bed as youngers, because of an earlier bathyphase. A desynchronization could also appear with aging (Czeisler *et al.*, 1999 ; Moore, 1999).

- A period shortening

It does not always appear, but really exists.

As a conclusion, aging causes changes in the circadian system. Since we know consequences of these changes on sleep quality and quantity, vigilance and performances, it is obvious that measures which would restore these parameters would be of noticeable interest.

7• MEASURES PROPOSED TO REDUCE EFFECTS OF AGING ON WAKE-SLEEP RHYTHM DISTURBANCIES

- Non pharmacological methods

- Behavioral approach

The hypnic system of aged people has a poor yield, the subjects spent more and more time in bed without increasing their sleep quality. The restriction of time in bed should limit insomnia : the gradual increase in wake period improves nighttime sleep depth.

- Sleep hygiene

Sleep being sensible to each behavioral modification, it is important to maintain a strict circadian organization, *i.e.* to have a stimulant wake, to avoid mental or physical exercise before going to bed and to have a regular awakening time.
In conclusion, a well organized sleep is more important than a lengthened sleep.

- Napping

This technique is widely used in sports and military scopes to allow a better tolerance to sleep deprivation. It consists in taking short sleep times, all along the day. A short nap before a prolongated wake, for a subject without sleep debt, maintains longer vigilance and performance (Dinges & Broughton, 1989). However, this method can not be used for a long time because recovery becomes less efficient after several naps.

- Photic stimulation

Exposure to light inhibits daylight endogenous melatonin secretion and results in a reduction of the secretion period during the night (Myers & Badia, 1995). Thus the nighttime peak becomes again important : the increase in

the circadian amplitude affects target systems and induces their resynchronization.
This method is not widely held, because it is only efficient with young and very old people. Moreover, its long-term effects still remain unknown.

- Physical exercise

An intensive nighttime physical exercise, during a shift work, seems to be interesting : fatigue and musculosquelettic symptoms tend to disappear (Van Reeth, 1998).

- Pharmacological methods

(Lagarde, 1991)

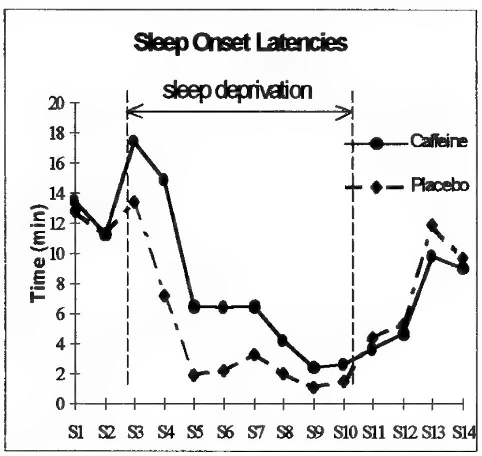
- Exogenous melatonin

Significative hypothermic and hypnotic effects are due to melatonin (Reid *et al.*, 1996). The nighttime bathyphase is associated to an increase in quantity and quality of sleep (Weitzmen *et al.*, 1982). As a consequence, hypnotic effects of melatonin should be due to the decrease in central temperature (Reid *et al.*, 1996).
An exogenous melatonin intake shortens stages 1 and 2 latencies of 40% and 25% respectively (Reid *et al.*, 1996).

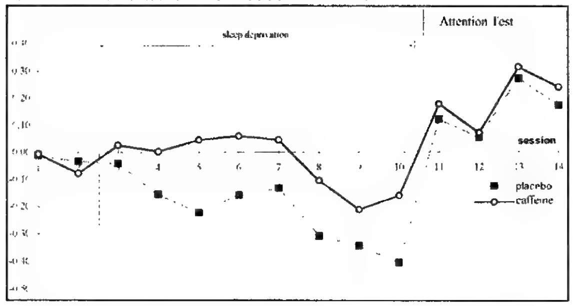
- Slow release caffeine (STINERGIC®)

It has already been presented in several communications in previous issues of this symposium. To sum up, it has an awakening effect and enhances vigilance and performance levels previously impaired.
During a sleep deprivation, it increases sleep onset latencies and improves attention test scores (Lagarde *et al.*, 1996) :

Sleep onset latencies (per session)



Scores of the attention test BATP :



- Modafinil (MODIODAL®, PROVIGIL®)

Modafinil is a recent molecule which stimulates vigilance. It acts by potentialisation of the α_1 adrenergic cerebral activity, without amphetaminic activity (no modification of the cardiovascular parameters, behavior, appetite, no inurement). Proportionately to the dose administrated, it restores or increases daylight vigilance levels. During a sleep deprivation, it abolishes nighttime arousals (Lagarde & Batejat, 1995 ; Lagarde, 1995).
It is prescribed in the case of narcolepsy with or without cataplexis and idiopathic hypersomnia ; it was used with success during the Gulf War.
It has already been presented in previous editions of this symposium.
At the present time, any study demonstrates the interest of modafinil in the treatment of aging sleep troubles. But it can be supposed that the morning intake of modafinil, in order to maintain a daylight waking state, should enhances nighttime sleep quality ; as in insomniacs as well. (Garma *et al.*, 1987).

- Benzodiazepine-type hypnotics

They induce sleep by action on GABA receptors. Their effects on sleep architecture are summarized in the following table :

PARAMETER	VARIATION
Sleep Onset Latency	↘
Nighttime Arousals	↘
Percentage of stage 2	↗
Percentage of stages 3 and 4	↘
Percentage of REM sleep	↘

Some secondary effects tend to limit their use, such as : daylight sleepiness, fatigue, vertigo, depression, dependence, anterograde amnesia, anxiety rebound, weaning syndrome.

- Non benzodiazepine-type hypnotics

Despite of their different chemical structure, they bound to the GABA receptors, but have different characteristics :

• cyclopyrrolone derivative : zopiclone (IMOVANE®)
Its effects on sleep architecture are summarized in the following table :

PARAMETER	VARIATION
Nighttime Arousals	↘
Percentage of stage 2	↗
Percentage of stages 3 and 4	↗
REM sleep	delayed

Any decrease in daylight performances has been notified.

• imidazopyridine derivative : zolpidem (STILNOX®, AMBIEN®)

It seems to be the "ideal" hypnotic :

PARAMETER	VARIATION
Percentage of stages 1 and 2	↗
REM sleep	delayed

It does not induce neither rebound of insomnia at the end of the treatment nor a decrease in daylight performances. It should be used without any disadvantages in military operations (Sicard, 1993).

8• CONCLUSION

The important modifications of sleep characteristics with aging lead to a decrease in its restoring effect as soon as 45 years old and to a decrease in daylight vigilance. These modifications may be explained in physiology and pathology by some changes in the endocrinous secretions, especially of melatonin. Some physiological and pharmacological countermeasures may be proposed : new hypnotics and psychostimulants can be used to correct these circadian troubles.

These measures allow military men, from 40 to 60 years old, to maintain satisfactory levels of vigilance and performance consistent with missions they must carry out.

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Working Memory, Age, Crew Downsizing, System Design and Training

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Working memory is a central component of many models of cognitive function and workload (c.f. Baddeley and Gathercole, 1993). The ability to store information on a short-term basis for rapid retrieval or to retain cues to aid recall of long-term information is often presented as a major bottleneck in human performance. Some models of human information processing (Pashler, 1998) place the bottleneck in the central processing phase between input and output and relate it to sequential processing, response selection or limited capacity processing, via a central executive. Many models of attention place the bottleneck between early in stimulus processing (Broadbent, 1957) or at both early and late stimulus procesing (Norman, 1968).

Wherever the bottleneck exists, or if its position varies with processing experience or attentional states, there has been a general consensus that the central processing phase is of limited capacity (Broadbent, 1958), from the very earliest work. This short term processing and storage capacity will be called working memory as termed by Baddeley and Hitch (1974). Working memory deals with memory processes and storage held in a quickly accessible store in preparation for processing or during the processing of information, where the store has limited or finite capacity[i]. Analyses of accidents in safety critical systems suggest that memory lapses are an important source of errors and serve to create fertile conditions for accident development (Redmill and Rajan, 1997).

It is likely that working memory holds the information to be processed, the results of processing and the operators used to process the information. Thus, capacity can be exhausted by complex operators, large bodies of information to be processed or multiple results following from operations. This can be contextualized in air-warfare in the following examples. An operator examining the Radar Warning Receiver (RWR) can see multiple traces from different headings and the frequencies on different headings may mean different things, this represents complexity in the data. The tracks on an RWR must sorted into friendly and potentially hostile forces, and in some cases coalition forces may be flying aircraft equivalent to those flown by hostile forces. The latter case, where friendly forces operate aircraft equivalent to hostile forces, represents a case where the operators and tests applied to sort tracks are more complicated and it may require data fusion by the man or machine to unequivocally identify tracks as friendly or hostile. The same complexity of sorting can generate multiple results where there are failures to unequivocally identify tracks because multiple solutions must be considered. Even where single tracks are shown on the RWR the separation of tracks may be such that multiple sources, multiple aircraft, appear to be single tracks.

Thus, even a simple sorting analysis has uncertainties and multiple interpretations may be required to prime the operator for alternative responses. Where alternatives are not brought to mind and place-marked for future reference the situational awareness of the operator is by definition weaker (Endsley, 1995a, 1995b, 1988). The significance of situational awareness in air-warfare can easily be appreciated by consideration of commentators and writers in the area of combat (Spick, 1999; Handleman, 1999; Rendall, 1997; Press, 1999). While the reduction in the number of alternatives considered by older experts, through judicious selection is possible, there are still likely to be difficulties in retaining place-markers in memory for the different alternatives, which has been accepted in reviews of ageing performance (Proctor and Dutta, 1995), such that memory performance

[i] *More recent analyses based on skilled memory (Ericsson and Delaney, 1999) consider the possibility that the limits are not as great as those observed in more abstract tasks within the laboratory. However, it remains a matter for conjecture how these limits are overcome by either functional or structural routes, which in turn leaves open to question what limits memory imposes on expert performance.*

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is still a key issue. There are kind interpretations of the older individual suggesting that more experienced operators are more selective so they simply consider the most likely alternatives. Such an interpretation suggests that older and more experienced operators would by definition be subject to the confirmation bias as a consequence (Huey and Wickens, 1993).

It is clear that any changes in working memory would be expected to have a significant effect on human information processing performance and some models of performance have specifically identified changes in working memory as causative in errors and changes in processing speed (Humphreys and Revelle, 1993). This interpretation is in direct contrast to the more traditional views of memory as 7 plus or minus 2 items (Miller, 1956) so beloved of engineers and system engineers (c.f. Chapanis, 1996). It should be noted that many design calculations assume that the 7±2 refers to data and take little or no account of the operator complexity, the number of steps (requiring place-keeping) and the generation of multiple potential results. Thus, many designs may seriously underestimate the memory load and even if chunking (Miller, 1956) of data takes place, or skilled memory usage takes place, the likelihood of forgetting or distortion of memory is very high. In addition, it has been predicted that states of fatigue will affect the capacity of the working memory and the rate at which information is processed. Thus, it would be expected that a number of factors may affect performance via their effects on working memory.

First, fatigue will decrease the capacity of working memory and increase the likelihood of forgetting. Second, fatigue will slow the rate of information processing and may exacerbate problems of capacity by slowing down the refresh rates of memory held in the temporary stores slaved to working memory. Third, any condition such as mental or physical stress and/or age which is likely to increase the rates of fatigue and the impact of fatigue will increase the limits on working memory performance. If this is compounded with increased workload because of decreased crew size this may create the conditions for performance failures.

Many of the more recent textbooks of skilled performance, such as Proctor and Dutta (1995) and reviews of human performance (such as Jones and Smith, 19992a, 1992b) acknowledge the interaction of age with factors such as fatigue and stress, with explicit recognition of the decrements relating to performance. Analyses of fatigue effects, clearly identify possible interactions between fatigue and memory performance which may be hazardous in safety critical systems (Caldwell, 1997). It is certainly true that older adults report fewer items in a delayed report tasks and the difference is more marked with increased delays in reporting, suggesting an inability to sustain information in sensory memory, prior to selection for transfer to working memory (Walsh and Thompson, 1978). There are also deficits in specific types of working memory performance and related activities, such as speed of information processing, storage of information in memory, and formation of recollections and associations (Proctor and Dutta, 1995), which degrade with age and are likely to have significant effects on performance in the highly dynamic and cognitively demanding air-warfare environment. It should be noted that each sortie requires the absorption of significant amounts of information relating to target disposition, threats and various other factors.

Integrative Human Factors

In many respects this represents a typical case where integrative human factors is required to acknowledge the range of operators using equipment, the conditions they operate under and the variation in the levels of demand. An older operator, with heavy task demands occurring after heat stress, long shifts and under time pressure represents the worst possible case. Training can help to improve memory performance (Ericsson and Delaney, 1999) but it cannot eradicate many of the basic effects attributable to fatigue, such as failure to execute actions as a result of interruption. It is known that experts tend to remember information more effectively than novices (Green and Gilhooly, 1992) but training may not counteract all the possible effects on working memory, such as stress or fatigue, which effect older individuals more. While it is possible that extended experience and training can reduce workload, by increasing automaticity, there are no such effective countermeasures to fatigue, stress or acute time pressure. Indeed, the catalogue of accident reports, failures to manage trained for events adequately and incidents or near misses, is replete with cases where these factors are possibly at work (c.f. Beatty, 1995; Brookes, 1996; Brookes, 1992; Faith, 1996; Stewart, 1992).

Many times the events or conditions contributing to accidents occurred or worsened at the change of shift, when operators were tired. Or, early in the morning when the body clock of operators is at an all-time low incidents have become serious accidents. There are likely to be significant fatigue effects which are a result of the sleep debt and circadian disruption resulting from operating out of the regular time zones. In addition, there are social effects such as seniority which comes from age and may make older operators reluctant to accept that they are making errors in such conditions. It is possible fatigue may make older individuals reluctant to seek assistance or confirmation when they are genuinely making errors. Consider the interpretation of events in Tenerife, where

two 747s collided on the runway, for many of these issues concerning age, seniority, ability to interpret rapid information exchange and the willingness to accept junior operator's input.

The Role of Working Memory

Working memory is essential for thinking, problem solving, and decision making, which is particularly critical in complex environments where multi-modal interfaces are used to manage multiple tasks with dynamically changing information. Indeed, failures in working memory or processing strategies adopted to circumvent memory limitations are frequently cited as contributors to accident and incident development in military systems, where such control systems exist (Redmill and Rajan, 1997).

If one accepts that military operations are uncertain, dynamic and unpredictable environments then the role of working memory becomes paramount in relation to decision making and planning. This is particular the case where operators are forced out of automatic operation, by novel or unexpected events, and they are required to interrogate data and ascertain the best possible course of action without obvious cues to guide performance, as more recent models of decision making would suggest (Beach, 1998; Klein, 1997; Mosier and Skitka, 1996). The older operator, struggling to keep their workload levels manageable and within their own cognitive capacity limits is ill-suited to handle unusual events. In addition, older individuals inferior ability to work flexibly may be related to the issues concerning working memory, attention, or both.

Executive Functions and Age

It is generally agreed that some of the most significant functions associated with decision making and planning rely on frontal-lobe functions (Kolb and Whishaw, 1996). These functions may be critically related to working memory capacity and the ability to inter-relate different items of information in explicit awareness.

> "After many years of neglect, the study of consciousness has forced its way back into the mainstream of experimental psychology. I have presented a case for regarding conscious awareness as one of the functions of the central executive component of working memory. I have furthermore suggested that its main advantage is that it provides a system that allows reflection and planning to replace a more direct reactive mode of operation." Baddeley (1993, p. 26).

It is worth noting that models such as that of Beach and Mitchell (1990) consider cases where individuals make straightforward decisions and simply adopt or reject a plan of action. This would present little difficulty to an individual in terms of the cognitive burden in working memory. While it is probably true that such decisions represent the most frequent case in air-warfare it is equally possible that the critical events are not as easy to manage and they are the cases in which the aircraft, the pilot or both are lost.

It is also the case that simple decisions in air warfare can be dependent on multiple sources of information that must be integrated, as will be discussed later, and this requires operations to create a single image that in turn drives effective decision making. Beach and Mitchell (1990) consider the case where each decision has multiple candidates where a single choice may be easily made or where a more protracted decision making process takes place. It should be considered that the memory burden for such iterative processing of multiple alternatives is overwhelming for an operator in a busy and hostile air warfare environment, particularly if they are flying alone i.e. in a single-seat aircraft. Each alternative must be recalled. each evaluation of each alternative and each operator applied to determine each alternatives value. It would be easy to lose track of alternatives tested, evaluations made and operators to apply. Put into the context of a stream of information from on-board sensors, off-board sensors and uncertainty the whole process would be frighteningly complex. It is easy to see why experienced operators frequently select the familiar options and inadvertently take the low and high risk choices because they fail to adequately assess the alternatives (Huey and Wickens, 1993). It is important to note that is exactly this type of information capture and information manipulation that is indicative of air warfare and other highly dynamic environments, it is also the same type of task where older individuals have more difficulty.

Working memory is usually conceived of as a mental workspace which contains activated memory representations that are available for processing (Stoltzfus, Hasher and Zacks, 1996). Although many have emphasised the structural aspects of working memory there are accounts which stress the functional significance of ancillary processes such as attention (Pashler and Johnston, 1998). Taken together the structural and functional accounts emphasise the importance of such processes in integrating new, recently acquired information with long-term information to generate appropriate responses to environmental demands

(Radvansky and Zacks, 1997). As authors have noted when attempting to make sense of a narrative relating a murder:-

> "To be successful you must mentally retrieve and integrate this information to create a mental representation of the situation in which the murder took place. Furthermore, you must be able to successfully retrieve this representation when there are later references to the crime situations you have experienced and read about." Radvansky and Zacks (1997, p. 173).

Consider that accidents, like that of the 737 at Kegworth, suggest that there can be a failure to integrate information absorbed at the start of flight and the later equipment failures observed in flight. In the Kegworth accident it is possible to speculate about the mis-reading of instruments but prior to that potential mis-reading were events suggesting different interpretations of the on-going events which the crew may not have been cognisant of at the point of impact. Thus, they did not review their fatal decision making error.

The same place keeping functions, for tracking sequences of events, must take place with regard to a specific sortie in which it may be possible to retrieve the wrong events concerning the current sequence of events. Indeed, the normalisation of experience and the casting of actual experience into schematic understanding was the basis of early work on long-term memory (Bartlett, 1932). What is likely to be gained in recall or retrieval with explicitly acquired schema is lost in corruption or distortion of events to fit with an existing prior schema. This may explain why more experienced operators are less effective at managing novel events when their performance is compared to more junior crews. Paradoxically, the greater body of knowledge available to experienced pilots may lend itself to greater difficulties in recalling the actual sequence of events without distortion. Thus, it is easy to see why more experienced pilots tend to be affected by the representative heuristic and are susceptible to the confirmation bias, as they have a potentially wider range of schema to shoe-horn the current events into. As a result it is easy to appreciate why older and more experienced operators are more likely to produce poorer responses to novel events (Huey and Wickens, 1993) because they tend to seek such processing shortcuts to avoid memory limits. Indeed, it may their experience of decreasing capacity which forces or encourages them to seek such shortcuts more frequently as time passes. Or, it may represent the tendency towards satisficing (Simon, 1955) where operators adapt their input to match perceived demand. Accurate "Situation Models" (Johnson-Laird, 1983, 1989) will undoubtedly effect decision making performance and may undermine those judgements made where information must be integrated without prejudice, derived from earlier experience.

Validity Working Memory as a Predictor of Pilot Performance

It is hardly surprising that digit-span recall tasks, which measure an aspect of working memory capacity, are significant predictors of pilot performance because of the highly dynamic environment pilots operate within. There are no attempts to measure the variations of working memory with fatigue, time of day and to consider the likely effects of fatigue on working memory performance though. It is blithely assumed that the capacity of working memory remains constant. Studies on control room staff working for the Police suggest that there are noticeable changes across the time of day and there were results indicative of differences with age (Murray, 1998) and these are supportive of the changes described in the literature (Proctor and Dutta, 1995). Anecdotal observations on 43 crews at a night Tactical Leadership Exercise certainly suggest that the same effects would be found amongst older aircrew. Older crews and supervisory staff experienced greater difficulty in retaining the information required to accomplish tasks.

Working memory may play another significant role in the development and maintenance of expert performance (Ericsson and Delaney, 1998). In addition, the use of more effective executive control of resources like working memory and attention, via meta-cognitive strategies, may be significant in achieving higher levels of performance during skilled or expert performance, without the imposition of an additional cognitive burden (Ericsson and Delaney, 1998). There are suggestions that ageing may result in poor recall of information recently processed because of changes in working memory (Stine and Wingfield, 1990). The effective reductions in memory performance with ageing has clear implications for situational awareness in the cockpit and the effectiveness of decision making.

Training and Age

The current philosophy for aircrew training favours the use of younger entrants. The syllabus for United States Air Forces trainees (Linares and Lloyd, 1996), for many different programs, is quite extensive and an early commencement is required to successfully complete the training with sufficient time to have a reasonable period of active service. There is a belief that enrolment of younger trainees will result in rapid training

because younger aircrew can more readily absorb the complexity of the new systems, particularly in fast-jet training. Starting crews at earlier ages would potentially give them a longer serving career at peak performance because they would be able to serve at younger ages for longer. However, it has been suggested that experience, through the application of schematically stored knowledge, can compensate for the effects of age (Hess, 1990). The use of prior knowledge to counteract the effects of ageing supports that view that greater training experience at an early age will help to future-proof the cognitive performance of operators against the future effects of ageing, as they approach the end of their service career.

Youthful entrants may have a number of cognitive qualities which may make them more suitable for fast-jet training, such as general processing speed, working memory capacity, the ability to acquire information, and better control of attention. There are clearly significant variations in these abilities in the general population which require that such aptitudes are selected in the recruitment phase. The contrast in these abilities and qualities is only likely to be significant when the individuals reach their late twenties and early thirties, when compared to school leavers (Schaie, 1983). If training commences in the late teens or early twenties there are likely to be fewer differences, none which are significant. Some textbooks suggest that there is a modest rise in verbal IQ across the twenties and little change in performance IQ - loosely associated with spatial ability (Belsky, 1990), so one might expect that training could commence in either the late teens and early twenties. The real issue concerns how long an individual can profitably be expected to serve before their performance deteriorates.

At the other end of the service, when aircrew are likely to be coming to the end of their career, there may be more significant effects. It could be argued that system developers should take adequate care to assess the cognitive demands of their equipment in relation to that group because they are likely make up a significant number of the serving forces as a result of the demographic shift in the population. There may be good reasons to retain experienced operators for longer in smaller serving forces to ensure the continuity of performance levels with expertise. Taken together with the time to progress from signing up to operational deployment, with the modern sophisticated weapon systems, any increase in the length of service will have a profound impact on cognitive performance in older personnel. Thus, in summarising the argument so far it has been suggested that age will play a significant part in performance directly via its effects on working memory performance or via the effects of fatigue, time of day effects and the rigidity or inappropriateness of thinking associated with biased cognition.

The trend towards smaller crew complements, at sea, on land and in the air, with the merging of roles across previously distinct branches of the services are likely to exaggerate the need for careful examination of the cognitive burden in future systems, as more is demanded of individuals. Modern fighter/strike aircraft, in swing or multi-role deployment, now require the pilot to execute air-defence and surface attack roles with the added complication of the single-seat aircraft, removing the valuable support obtained from the navigator or weapon system operator (WSO). The range of weapon systems carried are very wide and the parameters required to deliver the different types of package for optimum effect are varied, which only increases the burden on the single-seat operator. This in turn increases the likelihood of mode errors which are recognised as a common problem leading to major errors, incidents and accidents (Woods, Johannesen, Cook and Sarter, 1994)

Working Memory and Task Performance

Researchers, such as Engle (1996) have presented evidence that individual differences in the capacity of working memory predict performance in a wide variety of real-world information acquisition tasks and with respect to retrieval tasks under conditions of controlled and effortful search. The difference is not in information capacity per se but in the attentional capacity to maintain information. Taken with the earlier evidence of Pashler and Johnston (1998), this supports the emphasis on youthful selection and it clearly underlines the importance of both structural and functional aspects of the trainees inherent abilities. This would support the importance of selection based on task switching capacity and digit span performance, but open up the possibility of other factors playing an important part, such as meta-cognitive skills or executive control ability.

Interestingly, it has been found that examination of age differences in short-term memory using the digit span test indicate that there is little noticeable decline of capacity with age. If the task is subtly altered to require translation of the digits into reverse order, reverse digit span, there are deficits with age and this test is probably a more accurate reflection of flexibility of processing involving the central executive to monitor the process (Woodruff and Birren, 1983). Thus, automaticity and non-executive functions can be sustained over large periods of the life-span but the management of more complex processes which is a true measure of an effective functional working memory, cannot. This general view can easily be used to justify more careful consideration of performance evaluation and modelling with older

operators to ensure the long-term operability of new systems and equipment, particularly when the new systems include reductions in crew complement and increased reliance on individual operators. In simple terms, the more demanded of the individual operator the more care needs to be taken with the changes in operator capability with age, as the risk of failure increases. There should clearly be no simple reliance on the convenient 7±2 formula of earlier times. Indeed, one can argue that if operations of any complexity are required then the memory loading should not be greater than it needs to be because of the need for recall of the operators, applying them to process data and monitoring the results of those operations.

In conclusion, there are at least three major issues associated with changes in cognition in ageing aircrew. The first issue concerns the longevity of service. Longer periods of service may result in individuals, who are valued for their expertise, and who are too expensive to replace. However, the older individuals may be less capable of performing the highly demanding tasks required of them if designs are not evaluated with older crews in mind. The second issue, concerns the introduction of systems with reduced crew complements and increased automation with greater cognitive demands on individual operators. This makes it more expensive to train operators, increasing the need for retention, and it may result in a steeper fall in capability on the part of older operators as a consequence. The third issue is related to the merging of roles and the increased need for multi-tasking. The young minds of highly selected trainees are likely to be more capable of task-switching than the ageing aircrew but they will experience the same decline in performance with age.

Thus, the long-term prognosis for certain design choices needs careful consideration with respect to changes in cognitive function with age. Experience suggests that advances in information technology and agent-based decision support is unlikely to appear in the cockpit in time to compensate for declining cognitive performance in aircrew (Press, 1999). Thus, care must be taken to future-proof system designs against the well-documented decline in cognitive function with age.

The Bandwidth Problem

There are school textbook problems that frequently begin "It takes ten men two days to dig a trench, how many days would be required...". In air warfare this issue takes on new meaning because the question concerns the number of men and automated systems required to process information quickly enough to respond. This air warfare problem is altogether different for a number of reasons.

First, the duration of the task in the schoolbook problem can expand and contract in a manner that is impossible for operators in air-warfare. In air-warfare, the use of beyond-visual range weaponry, first look-first kill infra-red search and track (IRST), off-board sensing increases, and the move to reduced crew complements makes time of response an even more critical factor. A simple analysis of skilled behaviour indicates that increasing the number of stimulus alternatives decreases the rate of response, according to Hick-Hyman law (Proctor and Dutta, 1995) and that is what is happening in the air-warfare environment. The crews are presented with more information from many more on and off-board sensors, resulting in a greater qualitative range of behavioural cues. This in turn should slow the crews down because they have to resolve more information.

Second, the number of men involved in any task cannot increase easily because communication between operators in air-warfare has costs. In single-seat air-to-air engagements communication is a cognitive burden to the operator because they have to prepare exchanges and receive or acknowledge them. In air-to-ground or surface attack roles communication in the air is virtually impossible because of the need for stealthy ingress and egress. In tactical battlefield management of the air-to-air or air-to-ground crews the operators must co-ordinate the different strike, fighter, EW and SEAD assets to ensure that the attack is pursued successfully with the minimum number of losses on the friendly side. The effects of small changes in cognitive capability may not be observed in the capability to pursue the individual tasks but in the integration of the information into a bigger picture and the effective communication of that picture to others in the combined air operations team.

Third, the range of broadcast information from off-board sensors is about to increase as information is passed around the digital battlefield allowing different crews to have immediate access to imagery from reconnaissance UAVs and various other intelligence platforms (Thornborough, 1995; Press, 1999).

The increase in available information is happening at a point in time when the crew sizes are likely to shrink in the different platforms, with all fighter and attack aircraft moving to single-seat. There have often been comments about the capability of F-16 and F-18 single seat crews to take on the multi-role or swing-role attack capability because of the complexity of the information they need to absorb and the possibility for being overwhelmed by the torrents of information. It should be remembered that the temporal distribution of events within the single-seat cockpit could vary much more than that in a two-seat cockpit. The major point is the continuing reliance on the pilot to integrate the available information to make effective decisions and the

demands on their working memory. Any tendency for the pilot to shed tasks or to fail to process information would increase the amount of error in decision making and decrease the quality of performance outcomes. In the limiting case the pilot would become a victim but such difficulties could increase the possibility for blue-on-blue or collateral damage in abortive attacks as well.

There is a greater possibility for cognitive lockup with high rates of data throughput as the pilot struggles to maintain skill-based processing because the response to events is automatic. If unusual or unexpected events occur the pilot will find they have to quickly shed tasks in order to evaluate and then respond to the critical series of events. Even if cognitive lockup does not occur the pilot may be subject to thematic vagabonding as each event suggests a new perception of the situation. The high data rates, the poor quality of analysis, or the loss of significant information could jeopardise the quality of decisions taken as recognition primed decision making is undermined.

Thus, in a battlefield rich in information the greatest problem will be the integration of the information into good situational awareness. The adoption of crude large scale integrated visual displays, helmet mounted displays, multi-modal input/output will not improve the quality of performance because the rate limiting step is largely internal to the human operator. Even if presentation capability is improved the operators ability to capture the information declines with age as well.

It is the ability to absorb and digest information in order to synthesise a cognitive model of the world situation in order that effective decisions are taken which is the key issue. The use of automation, such as a Defensive Aids Sub-System to protect the aircraft is a good example of a technology that will not significantly improve this situation. On the one hand, a DASS can automatically dispense chaff, flares or other alternative EW decoys systems when the pilot is heavily involved in other tasks. However, the pilot may not be aware of the type of threat or the quantity if they are allowed to disengage from the defensive tasks, leaving the automation to manage itself. Thus, situational awareness is significantly impaired by a highly automated system because it encourages the development of monitoring or supervisory roles which humans are ill-suited to (Mosier and Skitka, 1996). The situation would be different if the DASS engages the pilot in a *sensible* de-briefing statement during, after or both during and after the activation of the system. Thus, the pilot would be able to improve their situation awareness by checking on the frequency of emitters and identifying the possible systems used. This could be instrumental in warning the pilot about the use of new systems with variable frequency emitters, new ranges or greater power which might undermine their own capability. Having such an on-board wild-weasel would be extremely useful. Any future demands for a zero-loss war using air-power will require effective use of electronic intelligence (ELINT) with immediate availability of access to information collected.

The major point is that any increases in sensing capability must be shadowed by effective sensor integration and additional interpretation by intelligent agents which are capable of communicating the *picture* in the way a good Weapons System Operator (WSO) or navigator normally would. A secondary point is that cognitive overload will seriously undermine the rate of learning as the capability to self-monitor and review progress or mistakes will be seriously curtailed. This in turn means extended and more expensive training regime.

Working Memory

Working Memory is a construct describing a system which involves the processing of an on-going stream of information. There are at least three different descriptions of where bottlenecks occur in the processing of information which are difficult to resolve within the available literature. One theory proposed by Wickens (1992) suggests that multiple processing resources exist which can process visuo-spatial codes or audio-linguistic codes and when tasks do not use the same resources they can occur in parallel. Another theory of processing suggests that input and output processing of information in highly practised tasks is largely accomplished in parallel and it is only complexity of the response-selection or intermediate processing that acts as a critical rate determining step (Pashler and Johnston, 1998). A third theory, developed by Baddeley and colleagues (c.f. Gathercole and Baddeley, 1993) suggests that both of the previous descriptions are correct. In place of the response selection or intermediate processing problem Baddeley has posited a central executive that is a limited resource needed to direct processing. In place of the processing resources Baddeley has proposed modality specific slave stores for information processed in working memory based around phonological and visuo-spatial storage systems.

The model accepted in the analysis of information processing during multi-task multi-modal processing, typical in air warfare, will affect the predictions derived and the strategies taken to resolve the so-called bandwidth problem. Care must be taken to ensure that the variations in memory and processing performance attributable to other factors are not forgotten in the process of adopting these different models for analysis purposes. The key issue is over what range performance would be expected to vary and what would be the limiting cases over which the total air-warfare task varies.

Working Memory in Air Warfare Situational Awareness

The best way to envisage the significance of working memory in warfare is to identify a task and then to consider the changes that might occur with crew reductions and then to consider the way in which limited working memory capacity might further impinge upon the performance associated with the different information processing tasks the operator(s) are required to accomplish. A good example, which applies to the air-to-air, air-to-ground, multi- and swing-role aircraft is the construction of a mental model of the on-going air picture.

The first input that both air-to-air and air-to-ground crews have access to is the Radar Warning Receiver, which in its simplest form can give the directions of the emitter and the frequency of the emitter. From the emitter frequency it may be possible to deduce the type of radar emitter and from that it logically follows the type of aircraft, surface to air system or surface ship which carries the system and the possible degree of threat. This is the purpose of electronic intelligence to allow operators to quickly establish the nature of the threat. It is equally possible to find that emissions are carefully controlled in duration or other aspects of their characteristics to confuse or spoof the operators ability to interpret the signal. Occasionally a receiver may incorrectly indicate the nature of the source and friendly and enemy forces are mis-classified. Thus, the Radar Warning Receiver is only one source of information from which crews can get information and it may not always be accurate. Thus, an additional task is monitoring the effectiveness of the system in use. A major limitation of the RWR is it provides bearing only, and both the range and the altitude of the enemy aircraft are unknown. To obtain those other sensors and information must be used.

Another type of information may come from advanced infra-red search and track system, like those pioneered by the Russian designers, to enable silent or emission controlled attacks to be pursued under the guidance of ground controller intercepts at long-range, with the closing end-game using on-board sensing. Another on-board sensor generally available to fighter and fighter /attack aircraft is the radar system which depending on its type and the signal processing capability may be able to find and track multiple targets. The problem with on-board radar is the emission of electro-magnetic signature which informs enemy aircraft of the presence and the type of the aircraft, which undermines the first-look first-kill stealthy capability. Radar is currently a necessarily evil which may be required to activate the seeker head at long-range to ensure a good lock in difficult conditions e.g. look-down position where ground returns must be separated from the target. If the operator prefers to remain stealthy then the only other alternative to on-board radar is surface or air based radar from surveillance aircraft such as the E3-D, AWACS aircraft operated by NATO and French forces, the E2-C Hawkeye operated by French and U.S. Navies, or the AEW Sea King variant. Airborne radar will provide relative bearings of aircraft around a Bull's Eye position but a major limitation is the accuracy of the altitude of enemy aircraft. Altitude can really only be given accurately by more local radar with data-links and that means switching on the on-board sensing. The major benefit of the off-board sensing capability is the capability to limit emissions to the times when it is actually required for driving weapons systems before the weapon's own seeker captures the target.

The major point of this discussion is the requirement to fuse information from diverse sources to ensure that the image created is validated by independent sources. Thus, the target's bearing, range, altitude, speed, radar cross section, its historic profile in combination with its known capability in terms of weapons and range, help predict its future course. In recent conflicts the ability of the coalition forces and the allied groups to effectively suppress airborne and surface based enemy air defence has meant that the opposition have been unable to mount an effective Defensive Counter Air (DCA) force. Thus, the requirement for accurate air picture may be underestimated because coalition forces were sorting small numbers of enemy aircraft and Surface to Air Missile (SAM) systems. This balance can quickly shift with evolving surface missile system capability and air-to-air missile capability. Thus, there is little room for complacency.

As one can imagine the construction of the air picture is quite a difficult task in and of itself. Thus, it forms quite a formidable task alongside that of flying the aircraft in difficult or hostile conditions. For example, large numbers of highly effective SAMs present a considerable threat which must be managed with on-board Electronic Counter Measures (ECM), decoys, jammer aircraft or chaff. Electronic Warfare (EW) assets or Suppresion of Enemy Air Defence (SEAD) are a limited resource, whether they are carried within a package as under-wing stores or on other aircraft as specialist units. Recent events have shown that such assets in the form of specialist aircraft like the EA6B Prowler represent a very valuable and scarce resource. The significance of this is the ultimate requirement of aircraft to defend themselves from air and surface threats with on-board systems than must be managed carefully and used wisely. In simple terms, this is another on-going task that requires a degree of intelligence to effectively use the assets and to prevent their depletion to the point where the aircraft is vulnerable to attack. These management of these systems normally

present a cognitive burden to the pilot or crew of the aircraft.

Thus, the management of Defensive Sub-Systems and Construction of the Air Picture represent highly demanding cognitive tasks which are mission critical, safety critical and more importantly time critical in that they require sure and certain responses to imperative cues. In air warfare, as in so many other aspects of warfare, speed is essential. This would indicate that defensive and intelligence gathering aspects of the air warfare environment require that information is accessible at speed from working memory. The delays or failure to recover information which can occur with retrieval from long-term memory are simply unacceptable with such information. Given the temporal imperative it might be expected that any continuous monitoring or performance task such as flying are expected to interfere with intelligence or defensive tasks. Thus, the shift from a two-seat cockpit to a single-seat cockpit could be extremely problematic if the pilot is unable to shed tasks such as flying, defensive sub-system management or intelligence gathering. The decline in specialist assets within all air-forces around the world means that individual crews now have to assume many more roles other than air-to-air or air-to-ground attack of previous fleets.

Thus, strategies are required to avoid the perils of cognitive overload possible in a single seat cockpit. For example, the integration of information from disparate sources using sensor fusion may help the pilot to make effective decisions about the threat levels from different enemy assets or the use of a intelligent agent to manage defensive aids may reduce the demands of that aspect of air warfare. However, it is clear that effective air-warfare performance would normally reflect the interaction of intelligence gathering with the management of defensive sub-systems. In some situations it may be better not to reveal one's position or intent by dispensing a decoys or chaff. The automation of the sub-systems, and both the management and monitoring of the tasks by the human in the loop require careful consideration. If the pilot is out-of-step with the intent, capability, responses or effects of the systems for sensor fusion or defence then serious consequences may ensue.

The key message that can be taken from this discussion is that air-warfare involves highly demanding tasks that impose significant memory burdens and require the integration of information, actions and consequences. If the sub-systems introduced to manage the cognitive burden address only partial tasks and fail to support the linkages between data gathering and skilled behaviour then performance can never be as effective as it would be in two-seat configuration. Many forces opting for the convenience of single-seat aircraft suggestively point to the success of aircraft like the F-15C and the F-16. However, mess rooms are replete with anecdotal stories of two seat crews in less effective aircraft defeating superior aircraft or *leakers* wreaking havoc on large packages as they overwhelm the SA of Combat Air Patrols (CAPs) with cognitive overload. It is worthwhile recalling that with single missile kills an aircraft like the Su-33 carries ten lethal weapons, the Su-35 twelve missiles, the MiG-29 six missiles and the MiG-31 up to eight. Thus, one aircraft can inflict significant losses on a single large package.

Stores Awareness

While it is possible that crews can check their weapons, it is better for them to aware of how many missiles they and their wingman have available and what type, so that decisions can be taken quickly about the decision to press on, in the face of strong opposition. A major point in favour of western forces has up until now been the capability of the weapon systems in particular the air-to-air missiles and particularly the AMRAAM whose capability as a force multiplier is undeniable. Recognising this only serves to underline the precarious nature of the balance of power.

Fallacy of Faster Throughput

The eighties was a period in which it was proposed that advanced interfaces would be developed. It was proposed that when these interfaces were adopted they would increase the capability of operators to process greater rates of information with naturalistic, sensor fused and intuitive interface technologies. This was the era of helmet technology that never was (except in Russia), the sensor integration / fusion that relied heavily on the human operator, the broad band interface that adopted speech to manage tasks like communication that had been mis-managed in previous aircraft, and which proposed virtual reality technology as a substitute for reality when there were well established problems with other forms of synthetic imagery.

The reason why the *pump more information in* philosophy could never work was the complete ignorance of certain key features apparent in the basic models of working memory. First, models of working memory proposed that a central executive would manage processing when tasks were difficult and unpredictable and it is a limited processing resource. Clearly low predictability and uncertainty describe the nature of air-warfare. Second, the central executive is a limited resource that has a finite switching time and this limits the number of sustainable of streams of conscious processing from different modalities or tasks. Thus, greater dis-integrated information would simply create a greater error rate with increased task switching,

incomplete processing and failed retrieval or misinterpretation as a consequence. Third, the central executive is required to sustain information in working memory so it is not simply the case that processing is delayed but that information is actually lost from consciousness. External access from displays is impossible because the signals change over time.

Consider again the combined RWR and radar image, from off or on-board sensing. It should be possible to intelligently manage this information in a complicated environment to predict the general location of threats in future epochs by tracking their movement. Thus, it would be possible to restrict the scanning of an active array radar and reduce the possibility of detection. At the same time it would be adequate enough to track potential threats and respond if the enemy radar locks on. This kind of predictive and restrictive use of radar might be accomplished by an intelligent agent. This is unlikely because of the degree of signal processing and computation required to visualise the information. It is task integration of this type which might allow the pilot to confidently share tasks with on-board automation but it is not likely in the next generation of aircraft.

Postscript

After presenting this paper it became clear that a number of related issues should have been addressed.

First, the issue of demands on working memory imposed by the design of systems can have effects throughout the period of service of the system operator which can in turn result in cascade effects from one period into another, with both costs and performance implications. A very complicated system can increase the initial training requirement and cost, as well as the risk related aircraft and pilot losses. The delays imposed by any protracted training can in turn shorten the effective operational or combat-ready phase of the operator's service, increasing the cost of delivering that performance per unit time. There are also no guarantees that the effects of poor design may not persist into the operational phase of operation and create further losses under high workload or special conditions. For example, the problems experienced with the computer controlled ascent and descent systems and moding in the Airbus seem to good examples of problem persistence into operational service (Woods, Johannessen, Cook, and Sarter, 1994). Failures to address working memory constraints might equally prove to be hazardous and some of the omission and commission errors in aircraft operation may be attributable to working memory failures or errors. At the end of the pilot's service any unreasonable demands from the interface upon the pilot's working memory may result in poorer performance, continued fatalities or the need for reductions in the period of active service. It is important to stress that failures in working memory would only be expected in the most demanding of conditions when the multi-task multi-modal aspects of the operators role becomes mission, safety and time critical. Given the dramatic changes about to occur in the nature of the aircraft available and their capabilities, the crew reductions proposed for future aircraft and their relationship to current practice it is difficult to predict the future outcomes. However, it is noticeable that strike aircraft like the F-15E Strike Eagle and the strike version of the Rafale will have two seats. It is also worth noting that the single seat versions of the SEAD F-16 have not been as successful as the Wild Weasel and EF-111 Raven packages in the Gulf War, although that may reflect changes in experience and knowledge of the opposition. Consistent with the view that crew size has a significant effect consider the vital role of the EA-6 Prowler aircraft in providing both soft and hard kill capability with regard to Suppression of Enemy Air Defence (SEAD) with its four man crew.

Second, the population of pilots or operators tested in studies is not homogeneous throughout the analysis periods used for examining performance with respect to ageing. This is explained by the commonly used phrase – "There are old pilots, there are bold pilots but no old, bold pilots". In simple terms, the process of de-selection or physical attrition through fatalities in accidents will remove those pilots who push too close to the edge of the envelope. It should be noted that no moral judgement is made in this respect because there are many military analysts that have strongly supported the need for such individuals in times of war (Vandergriff, 1999). Thus, attrition through accidents will remove those pilots of excellent quality in challenging manoeuvres and the poorer pilots who make simple un-forced errors.

Third, a major part of the argument proposed with respect to working memory is the combined effects of prolonged stress, fatigue, flying out of time zone, and flying at night. All of these factors in themselves can have small detrimental effects on performance but together, experienced chronically, they will have greater effects on ageing pilot as a result of their reduced ability to quickly recover. With smaller numbers in the potential pilot pool, careful consideration must be made concerning the benefits of age in terms of wisdom and the effects on likely performance.

Lastly, there are practical considerations concerning the retention of ageing crews because they may have experience which can provide useful insights for the more junior members of staff. However, care must be taken to retain only selected highly experienced staff with valuable experience, such as actual operational deployment or specialist skills, and this must be tempered

with knowledge concerning any changes in material operated by potential foes and changes in their doctrine. It is clear that training and operational matters are still affected by persistence of views drawn from cold-war experience and training. The modern battlefield has changed dramatically and the future generation of combat ready pilots must respond to that ill-defined challenge.

A Postscript on Working Memory in Skilled Performance

Finally, a recent paper by Ericsson and Delaney (1999) re-examined the issues concerning skilled use of memory in expert performers and it identified a number of significant issues with respect to such performance that have implications for the use of working memory in the relevant task domains. No matter what definition of working memory is accepted, and there are a number of alternatives, they all place stress on the place keeping and temporary storage of information using the mechanism of working memory. In the highly dynamic and context sensitive environment of air-warfare this function is vital to executing decision making in an appropriate manner based on conclusions drawn from current and previous information. Second, evidence reviewed by Ericsson and Delaney (1999) suggests that concurrent tasks with similar information processing requirements may not interfere but they fail to review the effects of semantic interference in concurrent tasks.

In air-warfare, given the levels of uncertainty, the use of spoofing and deception, and the consequences of failures, the crews may have to maintain several alternative hypotheses concerning the current trend of events which places a significant burden on memory. Ericsson and Delaney (1999) stress the need for extended practice in developing working memory skills in retrieving relevant information in skilled performance and largely associate that with extended practice of the skills. If the future systems have fewer operators, and more numerous and more complicated functional requirements for the remaining operators, it is clear that a conflict exists between the need to master all functions, to reach an acceptable level of skill in each, to develop skill in scheduling the different functions and to reduce the costs of training. This underlines the need for careful cognitive analysis of the functional requirements of training and the development of suitable strategies for enhancing the learning process to aid the development of skilled memory. There is clearly a very real danger of creating systems which genuinely take a lifetime to master but this a luxury that cannot be afforded when operational demands on combat ready crews are increasing. Combat roles could mean that the crew's life is terminated in advance of the final stages of skill development.

In conclusion, the ageing operator and their retention within the services present many problems and afford some advantages. There are issues touching upon the design of equipment, the selection of new recruits, the development of training, the maintenance of skill, the manning levels required, and other human factors issues, relating to the limits of human working memory. The potential information demands of future warfare cannot be dismissed and assumptions concerning the technological management and analysis of data have been so frequently challenged by failure that they need special consideration. Identifying working memory as a potential bottleneck can and should be a liberating discovery. The capability of the human processor in pattern recognition and in self-limiting of error, via insight, cannot be achieved by machine intelligence. Thus, all elements of the warfare system must accommodate the human decision maker and their memory performance to minimise the potentially fatal and catastrophic consequences of error.

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Prise de risque et vieillissement dans la marine

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Mots clés : âge, risque, prise de décision
Key words : age, risk, decision-making.

RESUME

Le vieillissement peut exercer des effets délétères sur les performances. Notre étude avait pour but d'évaluer une influence potentielle de l'âge sur la propension à prendre des risques, comportement qui intervient dans la prise de décision et donc dans l'efficacité et la sécurité d'une action. Nous avons donc soumis 130 marins, âgés de 19 à 41 ans, à notre outil d'évaluation de la propension à prendre des risques, l'EVAR. Les résultats de cette échelle visuelle analogique à 24 items, sont exprimés en 5 dimensions (F1 maîtrise de soi, F2 goût du danger, F3 énergie, F4 impulsivité et F5 invincibilité). Seule F3, est affectée négativement par le vieillissement. Les autres dimensions ne présentent pas de corrélations significatives avec l'âge. On peut donc conclure qu'un vieillissement modéré des marins embarqués aurait peu d'influence sur la propension à prendre des risques des opérateurs, les dimensions les plus critiques pour la sécurité (F1, F4 et F5) n'étant pas influencées dans cette tranche d'âge (19-41 ans). Cependant la dimension « énergie », qui semble décroître précocement, pourrait aggraver la fatigue et les besoins de récupération des équipages, en cas de vieillissement. De nouvelles normes de repos et de nouveaux rythmes de quart pourraient alors s'imposer.

ABSTRACT

As human age, decrements of performance may be observed. Efficiency in human/machine interaction is highly dependent on decision-making. Decision-making requires to compare, evaluate and manage risks, therefore, decision-making and risk proneness are related. The purpose of this study is to evaluate the effects of naval crew aging on risk proneness. We tested 130 male navy personnel, age range 19-41 years, with EVAR, a visual analogue scale designed to rate risk proneness. EVAR is composed of 24 items distributed among 5 factors: F1 "self control", F2 "danger-seeking", F3 "energy", F4 "impulsiveness" and F5 "invincibility". When looking at other human factor studies, F1, F4 and F5 are the more relevant factors to safety issues.

We observed a significant negative correlation between F3 "energy" and aging, whereas the other factors were not influenced by age. These results suggest that if navy crews are going to age moderately, within the 19-41 years range, risk proneness change is limited and should not be a safety issue in decision-making process. Although the decrements in "energy" observed with aging could lower the coping resource toward sleep deprivation and night shift, leading to new watch and rest schedule.

INTRODUCTION

L'âge moyen sur le porte-avions Charles de Gaulle est actuellement de 30 ans (18 à 52 ans). Un vieillissement modéré des équipages est une évolution possible du fait de la professionnalisation des armées, de l'utilisation d'une réserve active, de la technicité croissante des tâches qui impose des temps de formation plus longs ou un accroissement du ratio opérateur de haut/bas niveau.

Le vieillissement s'accompagne d'une maturation psychosociologique qui peut modifier les relations homme / machine ou opérateur / système. Par exemple, dans les dix ans à venir la population des contrôleurs aériens aux USA va subir un vieillissement significatif, lié à une cohorte importante recrutée lors de la grève de 1981 (4). L'âge médian passera ainsi de 36 ans en 1996 à 41 ans en 2001 et 45 ans en 2006, avec des conséquences potentielles sur l'efficacité et la sécurité du contrôle liées aux dégradations des performances avec l'âge.

Le vieillissement peut en effet être la cause de dégradations de performances lors de tâches difficiles ou complexes, où les capacités mnésiques sont constamment sollicitées (9). Tsang et Shaner, qui ont évalué les performances en situation de division d'attention, ont noté un effet délétère de l'âge, patent après 60 ans et quand un contrôle précis de tâche est exigé. Par ailleurs ces dégradations de performance pouvaient être modulées par l'expérience et la similarité dans la composition des tâches (15).

Le contrôle aérien, la gestion d'un centre opération ou d'un réacteur nucléaire, comme tout système complexe homme / machine, sont fortement dépendants de la qualité des prises de décision. Les décisions inadéquates sont une des causes principales d'accidents aériens (8). La prise de décision implique des processus complexes et de nombreux facteurs dont : les facteurs situationnels, les facteurs cognitifs, (mémoire, raisonnement, gestion des ressources), les facteurs de motivation et de personnalité et enfin les facteurs collectifs et sociaux (1). Dans toute action de notre vie quotidienne, de la plus triviale, comme manger ou s'habiller, à la plus complexe, comme

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piloter un avion, nous prenons constamment des décisions après avoir jugé, comparé et évaluer les risques. Le risque est inhérent à l'existence. La propension à prendre des risques d'un individu influence donc la prise de décision. L'absence comme l'excès de prise de risque peuvent affecter négativement la sécurité. L'excès de prise de risque est souvent cité comme cause d'accident, mais l'inaction qui accompagne l'absence de prise de risque est tout aussi dangereuse (12). Le jugement et la prise de décision recouvrent l'ensemble des phénomènes cognitifs qui prennent place entre la perception d'une situation et l'action. Ainsi l'éducation du jugement et de la prise de décision du pilote privé est devenue une priorité en aéronautique (3). Si les modifications psychosociales et cognitives qui accompagnent le vieillissement sont bien étudiées, les variations de la propension à prendre des risques en fonction de l'âge ne sont pas documentées.

Les seules données qui existent concernent la recherche de sensation, comportement lié à la prise de risque (14), et évalué par la Sensation Seeking Scale (SSS) de Zuckerman (16). Cette échelle est composée de 72 items, 40 dans sa version courte (6), distribués en cinq facteurs : facteur général, recherche de danger et d'aventure, recherche d'expériences, désinhibition et sensibilité à l'ennui. Chez 102 sujets, âgés de 15 à 62 ans (moyenne = 32 ± 12,6),dont 56 femmes et 46 hommes, l'âge est inversement corrélé au facteur général (r = - 0,528), à la recherche d'aventure (r = - 0,493) et à la recherche d'expériences (r = - 0,443) (7). Les sujets de moins de 30 ans présentent des scores significativement plus élevés pour l'ensemble des facteurs. Les hommes se distinguent des femmes par des notes supérieures pour les facteurs recherche d'aventure et désinhibition. Mais si la recherche de sensation peut être considérée comme un trait de personnalité, la propension à prendre des risques est plutôt un état, dépendant de la personnalité, mais aussi influençable par les stress environnementaux (13).

METHODES

Le but de cette étude est d'évaluer les effets d'un vieillissement modéré sur la propension à prendre des risques dans une population de marins. Nous avons développé et validé en utilisant la SSS, un outil de mesure de la propension à prendre des risques : l'EVAR ou EVAluation of Risks. L'EVAR se présente sous la forme d'une échelle visuelle analogique en 24 items. La structure en cinq facteurs (F1 maîtrise de soi, F2 goût du danger, F3 énergie, F4 impulsivité et F5 invincibilité) permet d'évaluer différentes dimensions de la prise de risque. Parmi les modes de fonctionnement pouvant affecter négativement la prise de décision car associés à une augmentation de la prise de risque, l'Embry-Riddle Aeronautical University a isolé dans la communauté de l'aviation générale le « rejet de l'autorité », « l'impulsivité », « l'invulnérabilité », « le syndrome du macho » ou excès de confiance en soi et la « résignation » (11). L'enquête chez des instructeurs pilotes de Beaumann et Crance a permis de classer par ordre de fréquence décroissante la survenue de ces cinq attitudes dangereuses. L'impulsivité arrivait en tête suivie respectivement de l'invulnérabilité, le syndrome du macho, l'anti-autorité et la résignation (3). L'EVAR présente donc des dimensions communes (F1, F4 et F5) avec ces modes de fonctionnement négatifs pour la sécurité.

Notre étude a été réalisée chez 130 marins, de sexe masculin, hétérogène dans leur spécialité (pilotes, cuisiniers, personnel de pont d'envol) et leur grade (matelots à officier supérieur). Ils étaient âgés de 19 à 41 ans, avec un âge moyen de 24,8 ± 4,7 ans. Les sujets ont rempli anonymement les échelles.

RESULTATS

Les scores des 24 items et des cinq facteurs de l'EVAR et les corrélations avec l'âge sont présentés dans les tableaux I et II. Une corrélation significative négative est observée entre l'âge et les items 1, 12, 22, 23 : plus les sujets vieillissent et moins ils sont enclins à pratiquer des jeux de hasard, à écouter de la musique à volume fort et rythme rapide et à conduire vite. Entre l'âge et les items 10 et 13 une forte corrélation positive apparaît : les sujets plus âgés préfèrent diriger qu'être encadrés et se sentent plus sûrs d'eux. Parmi les facteurs de risque, seul F3, l'énergie, présente une corrélation significative, et négative avec l'âge. Dans cette tranche d'âge, de 19 à 41 ans, la maîtrise de soi, le goût du danger, l'impulsivité et la sensation d'invincibilité ne sont donc pas affecté par le vieillissement.

TABLEAU I: moyennes (écarts type) des scores des 24 items de l'EVAR et corrélations avec l'âge.

EVAR : 24 items	Moyenne (écart type)	coefficient de corrélation
1 : jeux de hasard	25,53 (25,2)	- 0,24**
2 : accélérer / passer au feu orange	38,61 (29,3)	- 0,14
3 : réaction à la lumière éteinte	63,88 (27,7)	0,09
4 : éviter / affronter le monde	64,3 (23,0)	- 0,04
5 : plongeon d'une plate-forme	44,83 (34,1)	- 0,16
6 : envie de routine / aventure	74,74 (23,0)	- 0,04
7 : rechercher souffle du danger	47,09 (25,6)	- 0,14
8 : raccourci dangereux / sûr	5,.60 (29,2)	0,16
9 : négociation / affrontement	32,46 (24,9)	- 0,03
10 : préférer diriger / être encadré	70,00 (23,6)	0,38***
11 : privilégier action /raison	44,02 (25,6)	- 0,08
12 : musique à volume fort / faible	50,22 (27,3)	- 0,34***
13 : sûr de soi	70,41 (20,3)	0,30***
14 : discussions animées / calmes	45,13 (27,6)	- 0,05
15 : situation hostile renforce	70,19 (20,0)	0,07
16 : action face à chien menaçant	69,50 (24,8)	0,00
17 : réaction face à événement dangereux	65,10 (28,12)	- 0,05
18 : secours d'un noyé	65,32 (30,7)	0,09
19 : travail bien / peu planifié	20,56 (21,7)	- 0,01
20 : avoir toujours / jamais raison	59,52 (12,2)	0,17
21 : privilégier précision / rapidité	29,17 (22,0)	0,02
22 : vitesse de conduite	57,89 (23,4)	- 0,21*
23 : musique à rythme rapide / lent	57,88 (23,9)	- 0,34***
24 : tendance à prendre des risques	55,25 (20,6)	- 0,10

* $p<0,05$, ** $p<0,01$, *** $p<0,001$

TABLEAU II: moyennes (écarts type) des scores des 5 dimensions de l'EVAR et corrélations avec l'âge.

EVAR	moyenne	coefficient de corrélation
F1 maîtrise de soi	69,10 (14,2)	0,13
F2 goût du danger	48,83 (13,9)	- 0,11
F3 énergie	58,79 (16,4)	- 0,25**
F4 impulsivité	30,74 (14,2)	- 0,11
F5 invincibilité	54,47 (10,0)	- 0,00

** p<0,01

DISCUSSION

Dans cette étude nous nous sommes intéressés à évaluer d'éventuelles variations de la propension à prendre des risques en fonction de l'âge dans une population de 130 marins âgés de 19 à 41 ans. La fourchette d'âge étudiée est réduite mais est réaliste avec une projection d'un vieillissement modéré des équipages.

Les résultats de l'EVAR, échelle d'évaluation du risque, par items sont cohérents avec les données sur âge et recherche de sensations. Le recherche de sensation, trait de la personnalité, est lié à la recherche de risque et les études antérieures ont montré une corrélation négative entre âge et recherche de sensation, mais aussi une attirance plus importante pour les jeux d'argent (2) et pour la musique forte (10) des amateurs de sensations. Ces variations de la propension à écouter de la musique forte et rapide, et à jouer aux jeux de hasard semble donc directement liées à l'âge. La tendance à vouloir conduire plus vite quand on est plus jeune est aussi cohérente avec les données sur les accidents de la route chez les jeunes adultes (5). Vouloir encadrer plutôt qu'être dirigé et se sentir plus maître de soi quand on est plus âgé sont des tendances cohérentes avec l'évolution des fonctions et des responsabilités observée en milieu militaire.

La propension à prendre des risques et ses conséquences sur la prise de décision, donc la sécurité d'une action, est donc peu sensible à la variation en fonction de l'âge dans la tranche 19-41 ans. En effet seule la dimension « énergie » est affectée, et ce n'est pas la dimension qui influence le plus défavorablement la sécurité d'après l'Embry-Riddle Aeronautical University. Ces données sont cohérentes avec les résultats d'une autre étude que nous avons réalisée en milieu civil avec des personnes de 18 à 68 ans et où les variations de propension à prendre des risques étaient significatives à partir de 45 ans seulement. L'énergie dans la tranche d'âge 45-68 ans était significativement plus faible que dans les tranches 18-30 et 31-44 ans. La même évolution était observée avec l'invincibilité, cette dernière dimension étant plus péjorative en terme de sécurité.

CONCLUSION

Le vieillissement peut exercer des effets délétères sur les performances. Ces dégradations sont patentes après 60 ans et pour des tâches avec division d'attention et lorsqu'un contrôle précis est exigé. Notre étude avait pour but d'évaluer une influence potentielle de l'âge sur la propension à prendre des risques, comportement qui intervient dans la prise de décision et donc dans la sécurité d'une action. Nous avons donc soumis 130 marins, masculins, âgés de 19 à 41 ans, à notre outil d'évaluation de la propension à prendre des risques, l'EVAR. Les résultats de cette échelle visuelle analogique à 24 items, sont exprimés en 5 dimensions. Seule l'énergie, est affectée négativement par l'âge entre 19 et 41 ans. Les autres dimensions, maîtrise de soi, goût du danger, impulsivité et invincibilité, ne sont pas corrélées avec le vieillissement. On peut donc conclure qu'un accroissement modéré de l'âge moyen des marins embarqués n'aurait pas de conséquence significative sur la propension à prendre des risques des opérateurs, les dimensions les plus critiques pour la sécurité n'étant pas influencées dans cette tranche d'âge (19-41 ans). Cependant la dimension « énergie », qui semble décroître précocement et parallèlement aux capacités physiologiques, pourrait aggraver la fatigue et les besoins de récupération des équipages, en cas de vieillissement. De nouvelles normes de repos, de nouveaux rythmes de quart pourraient alors s'imposer.

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The Cost/Benefit of Aging on Safety and Mission Completion in Aviation Professions

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Summary:

The suspected detrimental effects of aging lead to concerns about aging pilots in civilian and, to a lesser extent, military flying. The typically superior cognitive ability of all pilots, and experience of older pilots in particular, however, render them a valuable asset and dictate they be carefully assessed when concerns about their cognitive ability arise.

Main Body:

Pilots face many environmental stressors, such as acceleration, vibration, noise, and elevated altitudes with attendant reduced oxygen. Other challenges, particularly faced by military pilots, include: Performing while fatigued, flying across time zones producing circadian desynchony, and being expected to be perpetually prepared to potentially engage in combat. While potential for performance (aptitude) fades with increasing age after an initial peak, the increased experience concomitant with aging serves to hone some abilities. While this paradox is true of all individuals, the complex and demanding environment inherent in aviation presents particular challenges. Nowhere is this paradox more apparent than in aerospace medicine. Aging aircrew present a diagnostic dilemma when they present themselves for aeromedical evaluation: It is counterproductive and misleading to compare certified possessors of the "right stuff" to their age cohorts in the general population when performing neuropsychological evaluations. An examiner needs a suitable reference group for appropriate norms. These norms, however, have traditionally not been readily available. The recent return of Senator John Glenn to space in his 78th year is a vivid example of the durability of the right stuff.

Neuropsychological findings based on the general population can only be generalized to the rarified sample of aviators with great caution, if at all. During a study supported by the Defense Women's Health Research Program, we tested 46 USAF female pilots (mean age 30) and 64 male USAF male pilots (mean age 29) and found the following:

Table 1. IQs of 110 experienced, nonreferred pilots

	Mean	Standard Deviation
Verbal IQ	120.36	5.57
Performance IQ	122.21	7.18
Full Scale IQ	122.95	5.35

While these levels of intelligence are striking and within the superior range of intellectual functioning, the standard deviations are of particular interest. While the general population has an average IQ of 100, the standard deviation is 15. These standard deviations suggest that this is a homogenous group. Other studies have reported similar results (5, 6, 22). IQs are calculated with reference to a cohort group clustered in age increments. Therefore, differential exposure to experiences and information, as well as physiological decline, is factored into each grouping. These results represent only a snapshot in time and do not address the possibility of future differential reduction in functioning. These individuals were either directly or at least indirectly selected to be pilots based on their extraordinary intellectual abilities (5). We don't know how well these extraordinary abilities are retained over the course of a lifetime, particularly when confronted with the stressors inherent in aviation, enumerated above.

While there may be times of increased vulnerability for (civilian) accidents at certain experience levels

The views expressed herein are entirely those of the author and do not necessarily reflect the policies of the United States Air Force or the Department of Defense.

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("around the 100 hour mark;" 20, *p.* 17; "between 100 and 300 hours total;" 12, *p.* 101), this factor is due more to experience than age. It is important to tease out the highly confounded effects of experience when considering aging (and vice versa). Eyraud and Borowsky (4), in a five-year study of US Naval pilots between 22 and 40, found that older, and hence probably more experienced, pilots had fewer mishaps. Of the accidents the older pilots had, they were due to procedural errors and violations of regulations. These violations of regulations suggest the possibility of overconfidence in the older Naval pilots.

We know a good deal about aviators who experience accidents, we do not know as much about aviators who do *not* experience accidents. It may be somewhat useful to calculate rates, based on gender and age groupings, bearing in mind the differential risk each group is likely to face. For example, younger pilots have exposure to risk as they are more likely to be represented in the "student" category, but experienced aviators are given the riskiest missions. Also, researchers need to adjust their data based on accidents per hours flown, while considering the level of risk of the mission.

In many ways, the medical concern over aging pilots is much less urgent in the active duty military than in commercial aviation. Active duty military pilots are range restricted in term of age. The military services of the US have age limits of when candidates may enter initial flying training; the youngest age possible is limited by the need for a college degree (placing a lower limit of approximately 21 or 22 years of age). The upper age limit in the USAF has typically been between 26½ and 27½ years of age at entry into flying training, with waivers up to age 30 possible. These waivers have been typically liberally granted. For instance, in 1998, 141 age waiver requests were processed, with 98 percent approved, producing an age range of those with age waivers from 27 years, 7 months to 30 years, 11 months. The other US services are roughly similar; those with higher age limits being less liberal in their granting of waivers. Even if a pilot were to fly for the entire twenty years of their active duty military career, which is highly unlikely, they would still be far short of the magic age of 60[1]. USAF pilots are expected to perform a minimum of 10, and usually 12, years of flying plus rated staff duty that benefits from their rated experience. The issue of age restrictions in the military is not related to age, *per se*, rather the issue is return on the expensive investment of flying training. The concerns include older pilot candidates being historically less likely to complete training, ending up in jobs not commensurate with their rank when they complete training, being disadvantaged by slowed reactions and other unfavorable physiological trends, and in short, suffering from a interaction of increased age coupled with lack of experience. Pilots who were not immediately assigned to flying duties due to a shortage of available cockpits, "banked pilots," faced the same challenge of increasing age without benefit of concomitant increasing experience.

Pilots who leave active duty and opt to fly for the Guard or Reserve may remain in a military cockpit even longer than they would in a civilian cockpit, as the military has no upper age limit on performing flying duties. Of even greater concern may be the relatively limited opportunities to fly, although many of these individuals also fly commercial aircraft. Flying dissimilar aircraft, however, increases the risk of committing the error of habit interference (negative transfer). This type of error is one that is actually *more* likely as a pilot gains experience, similar to the errors of complacency and overconfidence.

Numerous studies (as cited in 17 & 24; also see 25) suggest that while reductions in some cognitive abilities in pilots are offset by greater experience, *individual* differences tend to be greater than *between-groups* differences when looking at groups of young and old aviators. Similarly, air traffic controllers are more likely to commit an en route error as they age (after age 40); increasing experience, however, mitigates this effect (Broach, 1). Broach advocates a longitudinal study as he based his conclusions on a cross-sectional study.

[1] The US Federal Aviation Administration requires pilots operating under Federal Aviation Regulations (FAR) Part 121 (commercial pilots carrying 10 passengers or more) mandatorily retire upon reaching age 60. The FAA has been working on a system to calculate a pilot's *functional age* to individually determine when a pilot should stop flying in the interest of safety (10). Within several years, pilots who carry *any* commercial passengers will be required to comply with the age 60 rule under FAR, Part 119.

Studying age cohorts as they mature affords an opportunity to appreciate the motivation changes that impact professionals in the course of their careers. In any case, the benefits of increased experience, such as automaticity (the ability to do things without needing to think), may become overwhelmed during emergency and nonroutine situations.

What should be done when an aviator, due to a performance deficiency suspected of having a neuropsychological etiology, comes to the attention of an aeromedical examiner? For years, mass testing of applicants for pilot training was conducted with instruments from the experimental psychology arena and was specific to the branch of service developing the respective test. This technique limited the ability of the instrument to be used for later clinical assessment, if the need arose. Moreover, most clinicians are not familiar with these instruments, or at least do not know how to access an individual's results, and hence not likely to use them when conducting a clinical assessment (3). On the positive side, clinical tests are better safe guarded as they do not have guidebooks to aid test takers, at least not officially published ones, while selection tests may (see 26).

A recent example, drawn from his own account (9), is the case of aviation showman and septuagenarian Bob Hoover, who was medically grounded by the Federal Aviation Administration (FAA) due to concerns about his mental status and it's impact on his ability to fly safely. His contemporary and good friend, Chuck Yeager (also in his seventies), gallantly volunteered to serve as a "comparison group" when Mr. Hoover was offered a neuropsychological evaluation. Current efforts may provide a scientific reference base for these types of cases as the Neuropsychiatry Enhanced Flight Screening program archives cognitive functioning captured at the commencement of flight training (15). This battery of tests includes two that are mandatory for every candidate entering pilot training: Multidimensional Aptitude Battery (MAB; 11) and CogScreen-Aeromedical Edition (14). The MAB is an intelligence test closely corresponding (correlation = 0.91) to the Wechsler Adult Intelligence Scale-Revised (WAIS-R), the most widely used and respected adult intelligence test in clinical practice. The MAB, similar to the WAIS-R, determines verbal, performance, and full scale intelligence quotients (IQs) by plotting obtained raw scores against norms collected for various age groups. The CogScreen is not a test of aviation knowledge; rather it is a computerized neuropsychological screening instrument sensitive to cognitive functioning.

In addition to the obvious advantage of being able to neuropsychologically compare an individual to him- or her- self over time, such a collection of norms of high functioning individuals also provides a pool of age norms for high performance operators. Moreover, a cross-sectional comparison of fledging military aviators (mean age 23.5, n=512) to experienced airline pilots (mean age 44.0, n=584) on CogScreen clearly demonstrated the former excelling in tasks requiring cortical flexibility while the latter performs better in generic complex problem solving (2). A longitudinal study on the effects of aging on performance on CogScreen will be more meaningful as it will afford a within, as opposed to between, subjects design.

Case Vignette:

A medical doctor calls a psychologist to seek guidance about a pilot in his mid sixties. This aviator's supervisor is concerned with a recent onset of critical omissions, almost resulting in tragic consequences on more than one occasion during emergency procedures. This aviator, however, continues to successfully negotiate check rides and routine flights. The flight surgeon wants to send him to a local psychologist. You advise against this course of action due to your concern that this aviator would be compared against his age cohorts in the general population; subtle impairment in this aviator could easily go undetected. The psychologist advises referral to the tertiary facility where at least a baseline assessment could be established to gauge any dementing process.

Dissimilar to the safety consequences of cardiac disease, neuropsychological impairment is unlikely to result in *sudden* incapacitation. As the case vignette illustrates, neuropsychological impairment is likely to be subtle and not have a great impact on well-practiced skills. Rather, the senses, memory, reaction time, and ability to combat fatigue are likely to show the greatest decline (17).

Age is the address of where you are in life...

A person's chronological age is highly correlated with events that take place in the course of a lifetime. The lock-step structure of military career progression serves to make this even truer for military aviators. Motivation tends to change as a function of changing life circumstances (13). While middle age pilots may seem to be slowing down and may in fact be slowing down, they may also be responding to increased family responsibilities and a changes in life goals. Many may find themselves as part of the "sandwich generation" – caring for children who have not yet left home and concerned about aging parents. As increasing numbers of female pilots mature into senior aviators, it will be interesting to track their career and personal progression, which may differ markedly from their male colleagues as determined by their divergent goals (18). Moreover, female pilots have been shown to be more extroverted, agreeable, and conscientious than their male counterparts (16). While basic personality structure is unlikely to change during the course of an aviator's career, attitudes are likely to change considerably, which are directly related to performance (7). The work milieu during the course of an aviator's career changes, for example, the level of automation is steadily increasing. Those not raised using computers may be uncomfortable relying on them during flight. "With increasing cockpit automation, requirements for pilot aptitude are shifting from emphasis on 'stick-and-rudder' skills to interpersonal programming and monitoring capabilities-in short, management skills" (8, *p*. 488). It is therefore important to know what type of criteria was used when the pilot you are considering, from either a clinical or research perspective, were selected.

There are old pilots and there are bold pilots, but there are no old bold pilots...

Since the CogScreen is not influenced by experience in aviation and since airline pilots are largely mined from the pool of military aviators, it is reasonable to assume the differences are mostly a function of aging, with perhaps some selection and attrition influences as well. Another mitigating factor could be aircraft accidents that serve to slightly reduce the pool of aviators who go on to become civilian pilots. Such a confound is of interest for several reasons: aviators with relatively few flying hours (who are younger) are statistically more "dangerous" than more experienced aviators. Such a state of affairs may make it possible to "prove" that female aviators are more accident prone when the reality of any increased rate of accidents may be due to their inexperience and lack of representation in the more experienced group. On the other hand, experienced aircrew are typically assigned more challenging and hazardous missions (including training fledging aviators). We need to calculate the level of risk to appreciate the exposure faced by aviators, when determining the dangerousness of an aviator, or a group of aviators. It is unwise to simply linearly correlate age with accidents. Moreover, measuring performance by way of presence or absence of an aircraft mishap fails to recognize the low base rates of mishaps and the high prevalence of errors in all flights.

There are strategies for overcoming the detrimental effects of aging while retaining the benefits of experience. Morrow (19) argues that air traffic control messages be organized and presented in a standardized format. Furthermore, messages should contain cue words and intonation to minimize the possibility of pilots hearing what they expect to hear. The strategies to aid older pilots will aid *all* pilots.

Discussion

As the pool of available aviators decreases, aircraft become more complex, and training costs dramatically increase, better understanding of the issue of the aging aviator is paramount. Linear explanations, that do not consider level of experience and risk, have bedeviled aeromedical practitioners and researchers attempting to understand the relationship between aging and safety/mission completion. As fatigue is a bigger risk factor for older aviators, regardless of their experience level, specific assessment using sensitive instruments will increase safety and mission completion (23).

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EVALUATION DES PERFORMANCES PSYCHOMOTRICES ET MNESIQUES DES PILOTES EN FONCTION DE L'AGE

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SUMMARY

Pilots Memory and Psychomotor Performance Evaluation in Relation with Age.

Previous studies have shown an age related decrement in the performance of pilots tested in a flight simulator under intense attentional requirements.

The purpose of this experiment was to evaluate the relationship between age and aviation related tasks on performance.

We tested 31 military and 69 commercial pilots (including 34 former military pilots), age range 23 to 59 years, mean age 40 years old, on SEPIA, a motion based psychomotor evaluation device. SEPIA, similar to a flight simulator, is currently used to screen aviator candidates in the French Navy.

A significant correlation was observed between age and psychomotor performance and working memory. Younger pilots tended to perform better than older ones. SEPIA scores were also affected by experience, assessed by total flight time and years of flying. When looking at the different age groups, simulator and memory performance decrements were statistically significant at age 41 and beyond. Type of training and experience, either for fighter, maritime patrol or commercial pilots, did not influence performance. Self graded analysis of simulator performance was in agreement with the real score and not age dependent.

These tests did not allow us to evaluate flying skill of the participants, but only psychomotor capacity and adaptation to a new aeronautical environment. However, it is quite valid to take into consideration the age of the pilot when he transitions to another aircraft (after a first performance evaluation, naturally taking into account individual differences).

INTRODUCTION

En aéronautique civile ou militaire, près de 70% des accidents sont dus aux facteurs humains (1). Le pilotage, pour être performant repose sur des capacités individuelles sensorielles, psychomotrices et cognitives, sur une compétence et une expérience acquises lors de la formation et pendant la carrière et enfin sur des facteurs sociocollectifs.

Dans quelle mesure l'âge influe sur les performances en vol ?

Les ressources sensorielles qui s'altèrent avec le vieillissement sont régulièrement évaluées lors des visites d'aptitudes médicales systématiques. La fréquence de ces visites augmente avec l'âge, témoignant de la non-linéarité des dégradations physiosensorielles.

Les facteurs sociocollectifs sont influencés par le vieillissement. Les pilotes plus âgés ont plus de difficultés à faire face aux perturbations physiologiques engendrées par les rythmes de travail désynchronisés (2). Les capacités d'adaptation à de nouvelles procédures, d'acquisition de méthodes et d'intégration à un équipage, sont aussi réduites.

Les performances cognitives et psychomotrices peuvent être affectées par l'âge, particulièrement en situation de division d'attention importante (3). Dans ces circonstances, l'expérience, sous réserve de similarité des conditions, peut contrebalancer l'effet négatif de l'âge sur les performances. Leirer et Coll. ont montré lors d'une étude sur simulateur de vol, que des pilotes de 30 à 48 ans (moyenne d'âge de 37,6 ± 6,1) présentaient des performances inférieures à celles de jeunes pilotes de 18 à 29 ans (moyenne d'âge de 25,5 ± 3,6). Cette dégradation des performances liée à l'âge était particulièrement patente en situation de division d'attention importante, sollicitant à un niveau saturant les capacités mnésiques (4). Cependant dans cette étude, tout comme dans la précédente, un effet expérience a été suspecté, les sujets plus âgés ayant moins volé récemment que les pilotes plus jeunes.

Le but de ce travail est donc d'évaluer l'effet du vieillissement sur les performances de pilotage et les capacités mnésiques, en situation de division d'attention. Il est aussi de mesurer l'influence relative de la formation initiale sur les performances observées. Pour limiter les biais liés à une similarité de situation, soit l'équivalent d'un apprentissage, il n'a pas été fait appel à un simulateur de vol, qui aurait pu être familier à certains pilotes. Les tests ont été réalisés sur une plate-forme mobile d'évaluation psychomotrice appelée : « système d'évaluation des pilotes de l'aéronautique navale » (SEPIA), utilisée dans le Service Local de Psychologie Appliquée de l'aéronautique navale pour la sélection des candidats pilotes de la Marine.

METHODE

Population étudiée

Sur une période de six mois, cent pilotes professionnels volontaires – 31 militaires et 69 civils (dont 34 anciens militaires) – ont été recrutés à l'occasion d'une visite d'aptitude passée au centre d'expertise médicale du personnel navigant (CEMPN) de Toulon. Ils ont été répartis en quatre tranches d'âge d'effectif identique : 25 pilotes ont de 21 à 30 ans, 25 de 31 à 40 ans, 25 de 41 à 50 ans et 25 de 51 à 60 ans.

On distingue parmi les pilotes militaires :

- 19 pilotes de chasse,

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- 12 pilotes d'avions multimoteurs (liaison ou patrouille maritime).

Les pilotes civils - 65 pilotes de ligne et 4 pilotes de la sécurité civile - peuvent être répartis en fonction de leur formation d'origine en trois catégories :

- 35 pilotes de ligne qui n'ont jamais été militaires,
- 20 pilotes qui ont été pilotes de multimoteurs durant leur expérience militaire,
- 14 pilotes qui ont été pilotes de chasse durant leur expérience militaire.

Pour une exploitation cohérente des résultats, compte tenu d'une grande différence de moyenne d'âge entre les cinq catégories de pilotes définies ci-dessus, ils ont été réunis en trois groupes d'âge et de formation initiale homogènes :

- les pilotes de ligne qui n'ont jamais été pilotes militaires ;
- les pilotes de chasse et les anciens chasseurs reconvertis dans l'aviation civile ;
- les pilotes de multimoteurs militaires et les anciens pilotes de multimoteurs reconvertis.

Des critères d'inclusion stricts, définis ci-dessous, ont été imposés. Seuls ont été retenus les pilotes :

- brevetés et en activité ;
- d'avions uniquement (la plate-forme SEPIA reproduit un poste de pilotage d'avion) ;
- dont toute l'activité professionnelle s'est déroulée dans cette seule spécialité (les mécaniciens navigants ultérieurement formés au pilotage ont été exclus) ;
- médicalement aptes, sans affection aiguë ou dette de sommeil le jour des épreuves ;
- sans anomalie du sens chromatique et de l'audition (les sujets qui bénéficient d'une dérogation pour hypoacousie ont été éliminés) ;
- ne disposant d'aucune connaissance ou expérience de la plate-forme SEPIA.

La moyenne d'âge des participants est de 40 ans et 5 mois (écart-type 10,9), le plus jeune a 23 ans, le plus âgé 59 ans. Ils totalisent de 360 à 21 000 heures de vol et de 2 à 40 années d'expérience du pilotage.

Matériel

La plate-forme d'évaluation SEPIA est composée d'un poste de contrôle et d'une cabine d'aéronef reliés par un ordinateur central.

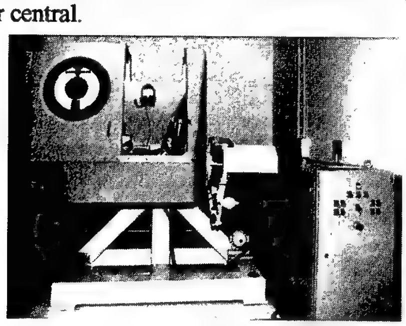


Figure 1. plate-forme SEPIA

Le poste de contrôle, réservé à l'expérimentateur, dispose d'un ensemble d'éléments de commande, de contrôle et d'enregistrement des résultats :

- un écran témoin, il s'y affiche les mêmes informations que celles qui figurent sur le tableau de bord du pilote pendant le test ;
- un PC de contrôle permet à l'expérimentateur de conduire le déroulement des différentes phases du test ;
- un ensemble haut-parleurs et micro assure un contact permanent entre l'expérimentateur et le participant ;
- une imprimante transcrit les résultats du test calculés par l'ordinateur.

La cabine (figure 1) est mobile autour de deux axes (roulis et tangage), surmontée d'une verrière opaque fermée durant les épreuves.

Le pilote, harnaché, dispose d'un casque audio par lequel transitent les consignes. Il a en face de lui un écran vidéo (21 pouces couleurs) représentant un tableau de bord rudimentaire d'avion léger. Il a pour sa main droite un joystick, un clavier numérique et quatre boutons-poussoirs de couleurs différentes, et pour sa main gauche une manette des gaz (figure 2).

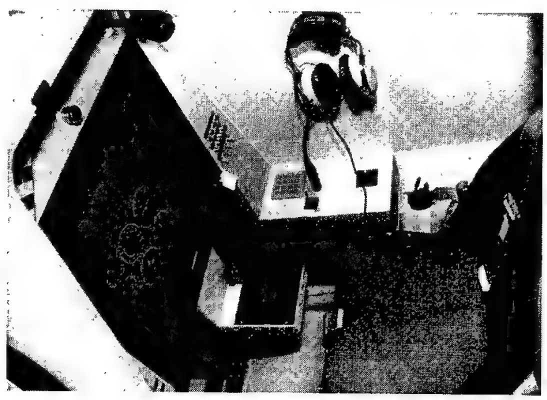


Figure 2. poste de pilotage

Protocole

Le protocole proposé à chaque participant est constitué de deux exercices d'environ sept minutes aux commandes de la plate-forme, au cours desquels des tests de calcul mental et de mémoire sont mis en œuvre.

La phase de pilotage comprend une succession de manœuvres classiques et élémentaires, définissant un ensemble de trajectoires. Les consignes sont du type : " montez à 6000 pieds, virez au cap sud à 20° d'inclinaison ...", elles sont transmises au moyen de messages vocaux préenregistrés, pilotés par l'ordinateur. Ils sont également inscrits en guise de confirmation sur un bandeau de l'écran du tableau de bord réservé à cet effet. Il est bien sûr demandé au pilote de respecter le plus scrupuleusement possible les paramètres de vol : assiettes, vitesses ainsi que les régimes moteurs. L'ordinateur possède en mémoire les trajectoires optimales, il compare en temps réel durant tout le test la trajectoire idéale et celle du participant. Comme il est

impossible d'être aussi précis que l'ordinateur, dans un souci d'exploitation cohérente des données fournies, des fourchettes d'erreurs admissibles ont été prévues, fourchettes dans lesquelles l'ordinateur considère l'écart acceptable : plus ou moins 100 pieds pour l'altitude, cinq degrés pour le cap, trois degrés pour l'assiette. Au-delà de ces plages, la phase de vol ne donne pas de point au participant.
Pour l'ensemble des deux exercices, une seule note est calculée par l'ordinateur. Elle correspond au pourcentage de phases de vol où l'écart avec la trajectoire idéale se situe dans la fourchette autorisée, c'est un reflet de la qualité totale du pilotage, elle en regroupe tous les paramètres. Un pourcentage élevé traduit donc une bonne prestation, le pilote a bien suivi les consignes.
Afin de détourner du pilotage de base l'attention des participants, il a été décidé de leur imposer des tâches annexes, à exécuter pendant le "vol". Ce sont des exercices de calcul mental et de discrimination visuelle qui vont, de plus, servir à établir le score des tests de mémoire.
Le calcul mental comprend deux opérations arithmétiques simples par période de vol. Elles apparaissent pendant 5 secondes sur le bandeau de l'écran. Tout en continuant le pilotage (sur une plate-forme instable, non compensée), le candidat doit se servir du pavé numérique situé sur sa droite, afin d'y entrer et d'y valider le résultat du calcul. Aucune contrainte de temps n'est imposée. Les stratégies mises au point par chacun dépendent de leur faculté de mémorisation, d'organisation du travail, de désignation de priorités dans les tâches. Par exemple, certains préfèrent terminer un virage avant de lâcher le manche et de rentrer le résultat, nécessitant ainsi un effort de mémorisation plus important. D'autres s'affranchissent du calcul rapidement quitte à perturber la trajectoire. D'autres encore utilisent leur main gauche, soit pour atteindre la pavé numérique (peu pratique), soit pour remplacer la main droite sur le manche pendant quelques secondes. A la fin de chacun des deux exercices, le pilote doit restituer oralement le résultat des calculs effectués.
La seconde tâche est une épreuve de discrimination visuelle. Dans la zone réservée aux opérations arithmétiques, apparaissent en alternance des disques de couleur. Des consignes différentes, transmises au participant avant chacun des deux exercices, l'incitent à prendre en compte de façon particulière telles ou telles couleurs, au moyen des quatre boutons-poussoirs colorés dont il dispose. Ce travail vient à son tour perturber la qualité de la tâche principale. Il est demandé au pilote, à la fin de chacun des deux profils de vol, de restituer oralement la liste de certaines couleurs observées, ce résultat fait également parti des tests de mémoire.
Les deux épreuves de mémoire sont notées sur dix : deux points sont attribués à la restitution du calcul mental et huit à celle des couleurs.
A l'issue des épreuves, il est encore demandé à chaque candidat de remplir une fiche de renseignements professionnels et d'estimer sur une échelle graduée de 1 à 10 la qualité de sa prestation.

Il convient enfin de préciser qu'aucune intervention de l'expérimentateur n'est nécessaire pendant toute la durée des tests, dans la mesure où l'ordinateur seul pilote les différents événements - tâche principale et tâches annexes -, selon un ordre chronologique préétabli ; cet ordre est le même pour tous les participants.

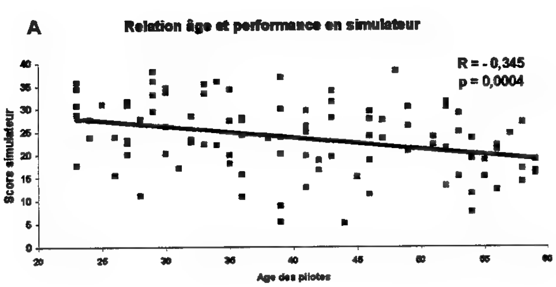
Analyse des données

Les données analysées et rapportées dans cette étude sont : les performances sur le SEPIA, les scores des deux tests de mémoire (test 1 et 2) et l'auto-estimation des performances, en fonction des paramètres : âge, années d'expérience, heures de vol, formation initiale des pilotes.
Suivant le cas, ces données sont analysées par régression linéaire ou par analyse de variance suivie des tests a posteriori adéquats. Les résultats des tests de calcul mental ne sont pas rapportés ici du fait du manque d'intérêt de leur analyse.

RESULTATS

Relations âge - performance

La meilleure performance aux commandes de la plate-forme (38%) a été réalisée par un pilote de 48 ans, la moins bonne (7%) par un pilote de 54 ans. Le score moyen est de 23,5% (écart-type 7,76). A partir de l'analyse statistique du résultat du vol simulé des cent pilotes de l'expérimentation, on observe une diminution progressive de la performance qui peut être corrélée avec l'augmentation de l'âge des participants. L'analyse de la régression linéaire entre âge et performance est très significative ($p = 0{,}0004$). La figure 3A montre bien cette tendance, la pente de cette régression étant négative.
On obtient également une pente négative en faisant figurer le nombre d'années d'expérience professionnelle ou le nombre d'heures de vol à la place de l'âge (figure 3B et 3C). Cependant, tant pour l'expérience professionnelle que pour les heures de vol, la significativité de la régression est moins importante qu'avec l'âge. La performance sur la plate-forme SEPIA reste stable et élevée jusqu'à 3000 heures de vol, elle diminue de façon significative à partir de 5000 heures de vol.



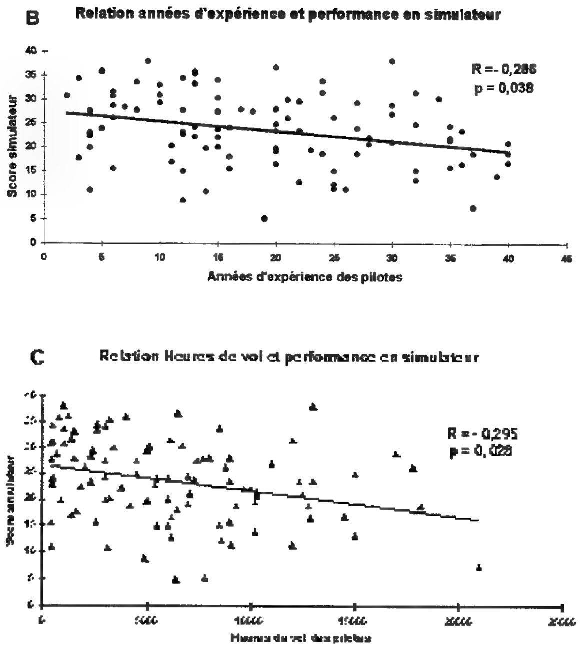
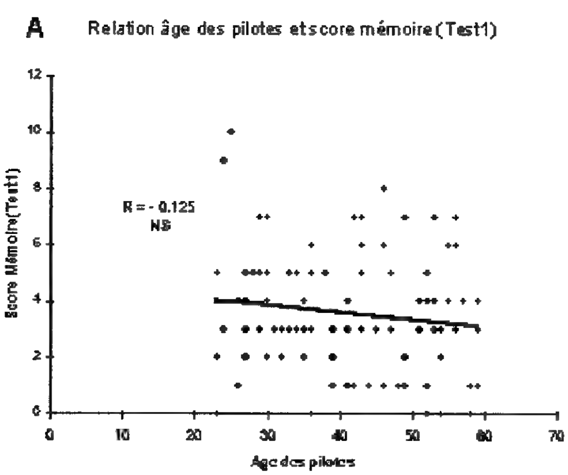


Figure 3. Relations âge, années d'expérience, heures de vol avec la performance

Relations âge - score de mémoire

Le score moyen du premier test de mémoire est de 3,66/10 (écart-type 2,2). L'analyse par régression entre âge et score de ce test s'avère non significative (figure 4A). En revanche, pour le second test de mémoire dont la note moyenne est 5,17 (écart-type 2,2), la corrélation avec l'âge est très significative (p = 0,0003). Le score diminue avec l'augmentation de l'âge, comme le montre la figure 4B.

L'existence d'un lien entre la performance en « vol » et le score du test de mémoire a été recherchée. En moyenne, ce sont les meilleurs aux commandes qui ont obtenu les notes les plus élevées au test de mémoire, et vice versa. Il existe un lien positif entre le score au simulateur et au test de mémoire (p = 0, 0002).



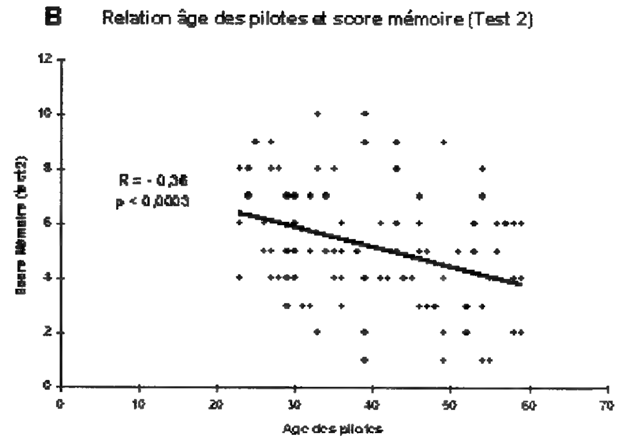


Figure 4. relations âge avec les scores de mémoire

Relations âge – auto-estimation de la performance (indice de lucidité)

La figure 5 montre un lien important entre la notation que les pilotes ont attribuée à leur performance et le score réel qu'ils ont obtenu sur le SEPIA.

Une analyse plus fine révèle que l'écart relatif entre auto-évaluation et performance réelle reste stable quel que soit l'âge des pilotes.

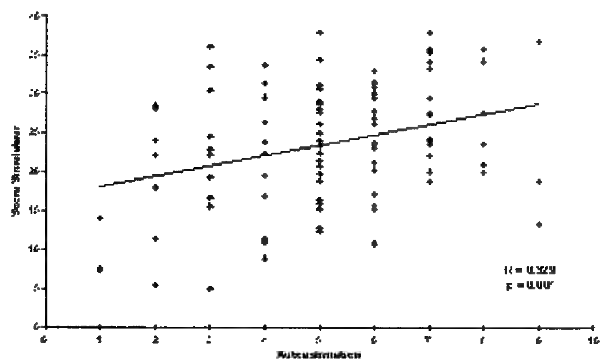


Figure 5. Relation auto-estimation et performance réelle

Relations âge - performance et score de mémoire, par tranches d'âge de dix ans

Comme cela a été mentionné, la population étudiée a été recruté par tranches d'âge d'effectif comparable. La tranche 21-30 ans obtient le meilleur score de performance sur la plate-forme, et la tranche 51-60 le moins élevé. Sur la figure 6, où les scores moyens au simulateur et au test de mémoire sont représentés en ordonnée et les tranches d'âge en abscisse, des diminutions apparaissent :

- pour la performance sur le SEPIA, la première décroissance survient en passant de la tranche 21-30 ans à la tranche 31- 40 et la seconde de la tranche 41-50 à 51-60. Un plateau est observé entre les tranches d'âge 31-40 ans et 41-50 ; bien que, statistiquement, ce soit à

partir du groupe des 41-50 que la diminution des performances devienne significative.

- pour le test de mémoire, la chute des scores relativement la plus importante semble se manifester entre les tranches d'âge 21-30 ans et 31-40. Cependant elle ne devient statistiquement significative qu'à partir de la tranche 41-50 ans.

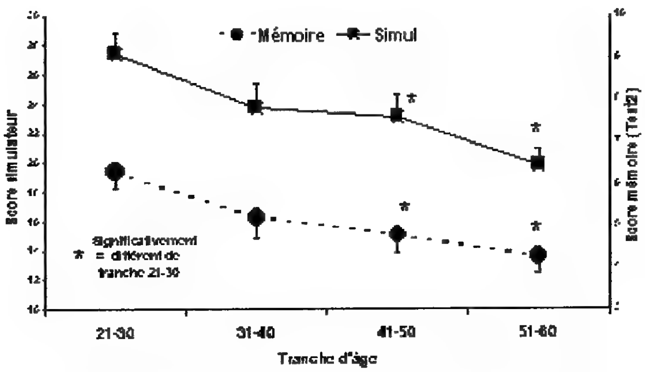


Figure 6. Performances au simulateur, test mémoire et tranche d'âge

Etude des performances en fonction du type de formation initiale

Que ce soit pour le score en simulateur ou le test de mémoire, on n'observe pas de différence significative (figure 7) entre les résultats des trois groupes de pilotes de formation initiale semblable : les pilotes de ligne qui n'ont jamais été militaires, les pilotes de chasse et les anciens chasseurs, et les pilotes de multimoteurs et les anciens pilotes de multimoteurs reconvertis dans l'aviation civile.

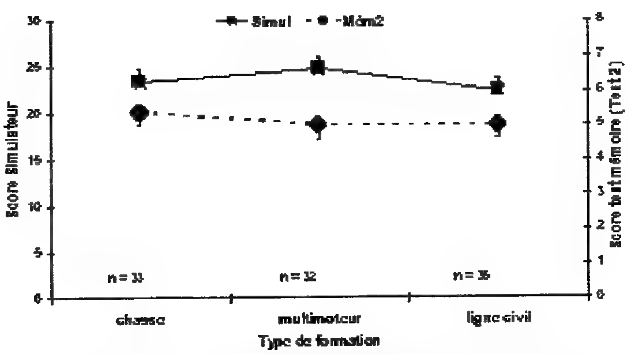


Figure 7. Performances au simulateur, test mémoire et formation initiale

DISCUSSION

Sur la méthode

Il est souvent difficile de comparer les performances de pilotes jeunes et plus âgés car ces derniers, notamment en milieu militaire, ont à assumer des responsabilités de commandement qui les éloignent des avions. Pour les 100 pilotes qui ont participé à ce test, le pilotage représente l'activité principale.

On pourrait imaginer que la plate-forme d'évaluation avantage les sujets les plus jeunes, rompus à tous les types de simulateurs modernes. Le SEPIA n'est pas un simulateur, il ne reproduit aucune cabine existante à l'heure actuelle dans l'aviation de chasse, de patrouille maritime ou dans l'aéronautique civile. De plus, le « vol » accompli pendant le test s'apparente plus à un exercice d'adaptation pure à un environnement qu'à la mise en évidence de qualités particulières de pilotage dans des phases programmées délicates (circuit d'attente, percée, finale, ravitaillement), ou lors de procédures d'urgence engendrées par un type de panne prévu.

Comme le montre la photo de l'écran de la plate-forme (figure 8), les instruments qui figurent sur le tableau de bord et leur localisation permettent, à ceux qui ne sont pas habitués à travailler sur des écrans cathodiques, de retrouver une disposition classique des informations de vol par le biais d'instruments répartis de façon traditionnelle. Ceux qui pilotent des avions plus récents, disposant d'informations regroupées sur un écran central, retrouvent, grâce au contexte cathodique, un environnement familier.

D'une manière très générale, une grande majorité des participants s'est plainte de l'instabilité de la machine ainsi que de l'absence de tout système de compensation, les contraignant à une vigilance de tous les instants. Ils ont également été surpris par la charge de travail, à la limite de la saturation. La plupart pilote en équipage et procède à des répartitions de tâches.

Les plus jeunes se sont montrés plus concentrés, moins démonstratifs ; les plus anciens ont davantage commenté leurs actes, surtout lors des phases délicates. Il semble que ceux-ci aient voulu rassurer l'expérimentateur quant à leurs réelles capacités : « si ma prestation n'est pas très bonne, sachez que je m'en rends compte et qu'en situation réelle, j'agirai pour rétablir une situation saine en répartissant la charge de travail, en temporisant, en faisant répéter les consignes... ».

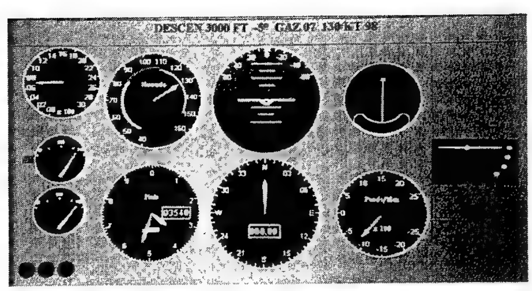


Figure 8. Ecran du tableau de bord

Sur les résultats

Dans cette étude, il semble donc que l'âge, plus que les années d'expérience, le nombre d'heures de vol ou le

type de formation initiale, ait une influence déterminante sur la baisse des performances et des capacités mnésiques. Ce constat rejoint les conclusions de plusieurs travaux scientifiques (5)(6).
Une chute des performances semble se dessiner au passage de la tranche d'âge 21-30 ans à 31-40, et s'accentue pour devenir significative pour les tranches 41-50 ans et 51-60. On peut affiner ce résultat en faisant porter le calcul sur des tranches d'âge de cinq ans. Avec cette deuxième approche, la chute de performance devient statistiquement significative à partir de la tranche 41-45 ans.
Le score du premier test de mémoire est faible pour l'ensemble des pilotes ; les participants ont vraisemblablement privilégié le pilotage au détriment de l'épreuve de mémoire à laquelle ils ont accordé plus d'importance dans le second test. Il est vraisemblable que la décroissance du score de mémoire constatée au passage de la troisième à la quatrième décennie, et même dès la tranche 26-30 ans, soit liée à une réduction d'activité mnésique professionnelle concomitante de la fin de la formation au pilotage. Actuellement les pilotes font peu appel à leur mémoire. Il ne semble pas que par stratégie, certains aient négligé le pilotage pour se consacrer plus aux tests de mémoire, puisqu'une meilleure réussite à ces tests est associée aux résultats les plus élevés en « vol ».
L'auto-estimation de la performance, quel que soit l'âge, reste en moyenne fidèle au score des exercices, cette capacité n'évolue pas avec l'âge dans ce travail.
En raison des importantes différences d'âge entre les catégories de pilotes qui ont participé au test – les militaires sont dans l'ensemble plus jeunes que les civils – l'analyse comparative des résultats par spécialité n'a pas été conduite. C'est le type de formation initiale qui a été retenu pour rechercher l'influence du mode d'exercice de la profession sur le résultat des tests. La comparaison des performances en fonction du type de formation initiale, incite à conclure que ces exercices n'ont pas avantagé les pilotes de telle ou telle spécialité.
Il est important de préciser que les performances mesurées au cours de ces tests ne permettent pas d'apprécier la qualité du pilotage des participants, mais plus leurs capacités psychomotrices et leurs facultés d'adaptation à un environnement aéronautique nouveau. Les exercices proposés font peu appel à l'expérience professionnelle, ils n'évaluent pas les dimensions collectives du vol, comme la coordination en équipage ou les rapports avec le contrôle aérien. Les moyens mis en œuvre dans cette étude n'ont pas favorisé les pilotes les plus âgés.

CONCLUSION

Les capacités psychomotrices et mnésiques de 100 pilotes professionnels volontaires, en situation de division d'attention, ont été mesurées sur la plate-forme mobile d'évaluation SEPIA. Une décroissance des performances corrélée avec l'âge est observée. Cette évolution des capacités psychomotrices et mnésiques, qui est significative dès la quatrième décennie, semble apparaître plus tôt, dès la troisième. Qu'elle est son influence sur le comportement en vol des pilotes ? Ce travail ne permet pas de le déterminer. Cependant, il paraît légitime de souhaiter que le programme de transformation des pilotes sur de nouveaux types d'aéronefs puisse être modulé en fonction de l'âge (après une première évaluation des performances, compte tenu d'importantes variations interindividuelles).

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Cognitive and sensory limitations with ageing

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Summary

Demographic developments, characterised by 'ungreening' and 'greying' of the population at the same time, necessitate the reconsidering of early retirement schemes in general and possible those of military professionals as well.
Keeping people in the services at older ages asks for continued training and education as the only way to keep people fit for the jobs and to prevent that their skills and knowledge become obsolete. Training and education has to be compatible with the sensory and cognitive changes with age as well the tasks and roles ageing people are best suited for.
Changes in the sensory functions are undeniable: the eyes have lost their accommodation function at 60 and, due to yellowing of the eye-lens, discrimination of colour differences in the blue part of the spectrum is no longer possible. Compared to young people only a third of the energy reaches the retina in older subjects. These kinds of sensory deterioration start already at the age of about twenty and similar patterns can be shown for the auditory and vestibular functions.
For cognitive functions a somewhat more differentiated pattern has to be sketched with a lower functioning of working memory but no deterioration or even increasing functionality of the semantic memory and a still growing domain expertise.
Despite functional changes, in general no performance decrement in actual work is found. This can be explained in several ways. One is that older people compensate for their reduced capabilities by using different task strategies. This may result in a different pattern of underlying skills used in doing the job.
Based on rather scarce research results, especially scarce for the functioning of people between forty and sixty years of age, still a number of recommendations for designing training and education for the older professional can be formulated. They derive partly from the sensory degradations with age, partly from the field of adult education. Findings in the latter field can be traced back to the changes in cognitive functioning with age.
The challenge, society at large but also the military face, is to make best use of a by necessity growing segment of older professionals, in such a way that also after retirement the older professionals are better prepared for a longer, more independent and active life.

Introduction

A growing concern with the loss of productive contributions by the elderly due to early retirement is paramount in most developed societies. The combined effects of greying of the population and the ungreening of it, threatens the balance between working and not working segments of the population.
For the military, this is a problem not yet fully recognised, because early retirement is part of most contracts of professional soldiers, the rationale usually derived from operational considerations. But when one realises that the problems of ageing workers nowadays are defined as problems of those above 40 years of age also the military should be concerned.
In the remainder of this paper, I will first show the projected demographic developments. Next I will give an overview of the cognitive and sensory limitations with ageing, with a particular emphasis on learning abilities. Finally, I will present an overview of recommendations for the design of learning environments for ageing adults.

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Demographic developments

Of all future developments, demographic ones are among the best predictable. In all western countries, the effects of 'ungreening' and 'greying' will lead to a sharp increase of the ratio of non-productive versus productive population segments.

Compared with 1996, in the Netherlands this ratio will grow from 0.90 to 1.40 in 2040, an increase in burden of about 55 %. (Even more dramatic is the foreseen fourfold increase of people aged over 85 years of which more than half will need daily care). From these figures it is clear that the participation of the elderly in productive positions has to increase because the burden of early retirement schemes as they are customary in a number of western countries can no longer be sustained. This will only be effective however, when the ageing workers have the opportunity to update their skills and competencies by regular additional training and education or otherwise in order to sustain their productive capacity in a fast changing world. On the moment this is hindered by a phenomenon called: 'experience-concentration', well researched in the Netherlands and probably also relevant for the other Western countries.

Experience-concentration.

Experience-concentration, a phenomenon, first described by Thijssen(1987), is characterised by its occurrence in the second part of the career, by a narrow focus of new experiences and learning activities, by a certain immobility and by a limited number of internal and external professional contacts. Main negative effects are a diminishing employability and a lower motivation to acquire new or updated qualifications by participating in educational activities.

Further research shows that the probable cause for this phenomenon lies in the way employees can interact with their organisational bosses. The latter usually operate from a stereotypical idea about ageing employees (hard to manage, only useable for long practised jobs) and since most middle managers have only a short time-horizon in their own ambitions, they tend to get the most from older employees just by giving them the already well-practised tasks they have proven to do efficiently. Since they also think that they are better off with a 'young' department or workforce, the resources for further education are more readily allocated to the young employees than to the ageing ones, thereby creating a self-fulfilling prophecy that experience-concentration is a characteristic of older workers and not the result of a lack of age-consciousness career development interventions.

Organisational strategies

Strategies for coping with the ageing employees vary among organisations. They can be characterised by two dimensions: accepting restricted employability or trying to enhance it; and time-horizon of intended effects: short or long.

Thijssen(1997) describes the resulting prototypical strategies as:

- replacement (accepting; short horizon)
- caring (accepting; long horizon)
- blocking (not accepting; burden of employability lies with the employee)
- development (not accepting; employability is also a responsibility of the employer)

Although the propagated choice is for the development strategy, this one is certainly not the one most encountered in practice. So, societal and organisational factors are both relevant for the fate of the older worker. But what about his own (diminishing or constant) capacities to change his fate?

Function-loss

One has to accept that most functions peak between 20-30 years of age (or even before) and that a number of them deteriorate fast, a number deteriorate slower and some of them deteriorate not at all. Relating this knowledge to work performance shows a somewhat paradoxical finding : work performance is hardly is affected by age. At least three different explanations can be offered. The first one is that one need not to have peak capabilities to do a certain job although an increase in workload may be the result. The second one is compensation by

cumulating expertise, which off-sets any deterioration in function. A good example is the visual discrimination capabilities of well experienced medical analysts, which perform less on not job related tasks. A third explanation is the use of different task strategies to compensate for function losses. An example is the way experienced, but older, typists look further in the to be typed text to compensate for a slower movement planning (Salthouse, 1984).
This shows that the relation between function loss and performance is not as straight as one should expect. A second finding is that the variation in amount of deterioration is rather large, so age itself is often a bad predictor of this deterioration. This is due to a complex interaction between genetic differences and unique life experiences like life-style, health history, exposure to contaminants, type of work and the overall physical and cultural environment.

Sensory functions

Sensory functions most obviously deteriorate with ageing. Starting at 20 years of age the eyes deteriorate in such measure, that at sixty almost no accommodation is possible and hardly any colour discrimination is possible in the blue zone. Furthermore, transmission of light through the eye-ball is only 33 % compared to healthy people 20 years old. Small details can no longer be detected, dark adaptation is substantially reduced, glare-effects are much larger. A comparable picture can be sketched for the auditory, smell, taste and vestibular functions. For the auditory functions the most obvious consequences are the lower ability for speech recognition and the lesser discrimination of sounds in a noisy environment.
Work as well as learning environments have to be adapted to these obvious changes in sensory functions in order to remain effective. Many problems can be directly related to these sensory deficits.

Cognitive functions

Almost all memory effects of ageing are connected to the slower processing of new information by the working memory; other memory functions do not degrade or get even better.
A distinction made by Howard & Howard (1997) is the following:

- working memory; allowing the short time allowed for pondering about newly acquired information
- episodic memory for remembering time-and-place coded experiences
- semantic memory for general knowledge about language and the world at large
- procedural memory for the knowledge how tasks have to be performed

Ageing effects are that the working memory deteriorates not so much in its capacity but in the ability to play with the contents of it. This can be illustrated by the difference in capability to 'hold' a certain number (e.g. a telephone-number) and the lesser capability to add in memory all the constituent numbers.
The episodic memory shows large deterioration with age. Crucial is the loss of remembrance of place-and-time cues of a memory. Such cues are instrumental for the ability to discriminate between general and specific information but also for discrimination between reliable and unreliable information.
The semantic memory does not show deterioration with ageing. Semantic knowledge and conceptual knowledge remain intact or even improve with old age. Only fast retrieval is sometimes a problem.
Procedural memory support all acquired behaviour but remains largely unconscious. Howard & Howard (1997) discuss three forms:

- classic conditioning
- skill acquisition
- priming

In classic conditioning (the Pavlov response) it is found that lengthening the time between unconditional and conditional stimulus gives conditioning effects comparable to younger subjects. The earlier idea that older people are less conditionable was proved wrong; only the *conditions* have to be adapted.
For skill acquisition a distinction has to be made between primarily perceptive-motor skills and cognitive skills. Perceptive-motor skills are more slowly acquired by

older people and they reach only lower skill levels. For the cognitive skills, acquisition is also slower but the ultimately acquired level is task dependant.
Priming is the memory phenomenon that due to earlier experiences with a certain item this item will more readily be remembered in the context of a new assignment compared to equally appropriate but not earlier experienced items. Asked to produce names of animals, animal names already addressed in an earlier context are more likely to emerge. The priming effect is not age specific, while the answers to the explicit question to name animal names, previously mentioned, do show an age effect (episodic memory).

Language and communication
In many work situations language and communication skills are crucial. For oral communication the slower processing speed of the working memory presents a functional limitation for listening and comprehension. To make things worse, also the capacity to discriminate between 'signal' and 'noise' (the 'cocktail-party' effect) diminishes with age. These negative effects can (partly) be compensated by the accumulated knowledge and verbal capacity of the elderly. They use their knowledge of linguistic structures and probability of what will be said next to overcome these sensory and cognitive limitations.
Reading written material is a very complex process, consisting of roughly the decoding of the recognised letters in words, the retrieval of the meaning of words in the mental lexicon, the construction of the meaning of the strings of words in a sentence and finally the integration of the meanings of a string of sentences in a story scheme or a theme. This process is dependant on the written material at hand, but also on all the inferences added to it on the basis of earlier experiences.
Spilich (1985) discusses the age related changes in this process and concludes that the way of verbal instruction and design of manuals has to be adapted for the elderly.

Problem solving
Problem solving is a capability, that clearly deteriorates with age, but only for new domains. Charness (1985) reports studies of expert players of bridge and chess which show that hardly any ageing effects can be found. Accumulated experience is transformed in a very domain specific expertise, relying much more on pattern recognition instead of analytically derived solutions, the latter being more vulnerable to the effects of slower processing speed or capacity of working memory. The development of this kind of fast pattern recognition takes however thousands of hours of playing.

The discussed losses in function can not only directly influence work performance, but also in a more indirect way. Panek (1997) describes an example: when the auditory function degrades, this can have as consequence that in a work setting orally given instructions are misunderstood, leading to an insufficient work result. This can provoke criticisms by colleagues because the unit target is not reached and this in its turn may lead to stress and subsequent (mental) withdrawal by the elder employee. The latter reaction strengthens the possible already existing stereotypic image of the older worker as slow, unable to perform and withdrawn. Such unwanted effects can only be prevented by insight into the possible function losses and the often simple measures to compensate for them in a work environment and by adapting the work to the specific capabilities and limitations of the elderly. To this belongs more opportunities for additional education and training instead of the more usual exclusion of these opportunities. Such schooling and additional training can only be effective however, when due care is given to the other ways of learning by the elder employees.

Learning by the elderly.
Given this review of function losses with age, the image may emerge of the elder employee as half-blind, slow, forgetful and hardly employable. This is at variance

with the empirical findings of sustained productivity implying that function losses are compensated in some way. Already discussed is that elder employees need more time to learn something new, and that their level then acquired is task dependant.

Charness (1989) even states that: ' ..3 (additional) minutes of practice per year of age differences is all that it takes to eliminate age effects..'

This seems rather optimistic but underscores the permanent learning capability of the elderly as long as sufficient time and good coaching is provided.

Some research has been done on the functioning of elder commercial aeroplane pilots. This group is interesting because the public image of them is that pilots have to function at top level and thus have to be young. Also they have to learn to adapt to changes in the work environment since due to technological developments and societal changes in mobility patterns this environment changes rapidly (congestion's in the air, air traffic control, automation). Theoretically, one could expect an increase in accidents with older pilots involved, but the reality is different. Morrow & Leier (1997) report on accident statistics, showing that exposure corrected accident rates are high for younger pilots, decrease from 30-34 years of age to reach a plateau for pilots in their fifties and increase after the age of 63 is reached. The most likely explanation is the compensation of function losses by accumulated experience. This is no longer effective when on introduces new tasks and new aeroplanes. In adapting to large changes in procedures and aeroplane control older pilots do have more trouble of formerly acquired knowledge and habits than younger pilots. This is functionally caused by a diminished capability to ignore irrelevant information. Morrow & Leier (1997) advocate an approach in which the design of displays (visual as well as auditory) and air traffic procedures is adapted to the reductions in sensory and cognitive capabilities of the elder pilots and that conversion training departs from the already acquired knowledge and skills.

Compensatory mechanisms

To offset sensory and cognitive limitations due to ageing, people use compensatory mechanisms. Earlier, it was mentioned how elder typists compensate for their slower motor programming capacity by looking further ahead in the to be typed text. Also Charness (1989) gives examples of the way elderly circumvent the problems associated with reduced capacity of the working memory by more reliance on pattern recognition and more specialised procedural knowledge. This not only enhances performance but also reduces the demands on attention heavy mechanisms. This exemplary evidence is now available for certain domains but is in no way general enough for work tasks as normally to be encountered. One has to conclude that much more research is needed to determine compensatory mechanisms in a variety of working environments, in order to be able to design effective education and training for the elder employees.

For the moment it seems wise to rely on the provision of a varied bundle of approaches for delivering training and education for the elderly, since they are by no means equally affected by age related general effects and do also have quite different histories. Still some general guidelines can be provided.

They are partly based on the general differences between the young and the elderly with regard to learning style, motivation, preferred way if information presentation and learning context and the match with earlier acquired knowledge and skills. Above this, one has to consider the possibility that for the elderly performance is based on a different profile of capabilities involved.

Adaptation of the learning environment to sensory function loss.

A number of rather basic adaptations can be suggested:

- avoidance of all irrelevant, distracting and noisy information
- use of standard place and colour coding
- higher illumination of the workplace, such that glare is avoided.

- For verbal communication: bigger letters with more contrast, sanserif letters are recommended.
- Avoidance of colour coding in the blue area
- Suppression of distracting background noise
- Oral communication: slower and more redundant with correctly constructed sentences and a sequence avoiding the need to still remember earlier information for being able to interpret information given later

Adaptation of the learning environment to cognitive function losses.
From the literature on the learning of adults a number of educational principles can be derived (Thijssen, 1996):

- Activation of the learner and avoidance of 'receptive' learning; this is explainable by the better remembrance by the elderly of information acquired during own activities as compared to classroom receptive learning.
- Avoiding straight memorisation; due to the weaker function of the episodic memory (retrieval cues) this is an ineffective strategy; when still straight forward information has to be remembered (pin codes for instance) mnemonics can be used; elderly are certainly able to use them.
- Providing feedback in very specific form
- Providing many feedback instances; the wealth of earlier experiences easily leads to wrong interpretations of the presented information so they have to be corrected as soon as possible.
- Providing a coherent frame of reference in which as much as possible relevant pre-knowledge is incorporated. In the change from typewriters to text processors much errors could be retraced to the old knowledge about typewriters no longer adequate for the text processing software. One can also argue that the use of ICT jargon as 'files' instead of 'documents' was not very helpful in making the transition.
- Making clear the relevance of acquiring the skills the course is directed at; this is more readily accomplished when providing modules which allow for direct application on their own.
- Avoiding all forms of competition. This is counterproductive and can give rise to demotivation.
- Creating a social and supportive learning environment by providing guidance in a positive, protective way, by much social support and by stressing equality in the interactions of teacher/learner.
- Programming of learning activities such that any time pressure is avoided, learners can individualise the sequence of activities and can take their own time. The program has to be transparent, flexible and open. In such way the program can encompass the larger variability among the elderly, e.g. the differences in learning speed and preferences. Time pressure only magnifies age-effects and is counterproductive for storage of the learned material in memory.

Concluding remarks
A hot topic is the introduction and use of ICT in numerous workplaces and for the access to services. This necessitates digital literacy of large segments of the population. On the moment, use of ICT by the elderly is scarce. Morell & Echt (1997) cannot explain this by a lack of motivation or capabilities with the elderly. They propagate the introduction of ICT in such a way that immediate, meaningful use is possible. ICT competencies thus have to be further developed by actively using it for doing one's work, solving real problems or getting access to needed services. Acquiring ICT competencies certainly can enrich one's life wen getting older by enhanced self-supporting and stimulation of cognitive functioning. It can also help in overcoming reduced mobility and the often found reduction in social contacts.
Studies on developments during the course of life show large influences of work circumstances on cognitive development or retardation in the adult (Schooler & Schaie, 1987). Work, characterised by complexity, self-guidance and variety

promotes further cognitive development. Many work places do not yet show these characteristics, thereby inducing the reliance on long time routines and an earlier cognitive deterioration than is necessary. The societal challenge is to give much more attention to the potential of the growing segment of older workers and retired people. The known variability of the elderly on numerous characteristics should be recognised and translated in more individualised schemes of retirement.

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NEUROPSYCHIATRIC AEROMEDICAL REFERRALS: DO TRENDS VARY WITH AGE?

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Summary

Four hundred eighty one records of aviators evaluated at the Neuropsychiatry Branch of the USAF Aeromedical Consultation Service were reviewed to assess diagnostic trends among this group. Sixteen psychiatric diagnoses were variously represented in the sample with relatively mild disorders (reactive disorders -- 19.7 percent, other psychosocial problems -- 15.2 percent, and neurotic disorders -- 13.3 percent) accounting for nearly 50 percent (48.2) of the disorders. Younger aviators aviators were significantly less likely ($p<.001$) to be seen for evaluation than older ones. Finally, diagnoses were not evenly distributed across all age groups; some diagnoses were more strongly associated with some age groups than others. Overall, results suggest some differential vulnerability to neuropsychiatric conditions depending upon the age of the aviator and the diagnosis in question.

Introduction

Characteristic age of onset varies among neuropsychiatric disorders. Some, such as autism, are diseases of childhood; others, Alzheimer's disease, for instance, typically begin in the later stages of life. Similarly, military aviators face varying stresses throughout their careers. The initial challenge of pilot training is followed by those of flying with an operational unit, upgrading skills, engaging in "real world" missions, and often extended and frequent separations from their families. Toward the end of an aviator's career are the combined potential psychosocial issues of increased supervisory and leadership responsibilities, preparation for retirement, and adjusting to an upcoming "empty nest" at home. Given the varying biological clocks of neuropsychiatric illnesses and different stresses throughout an aviator's career it may be that there is a relationship between disease onset and career stage. The present study examines this issue. The records of aircrew members who were evaluated at the Neuropsychiatry Branch (ACS-N) of the United States Air Force (USAF) Aeromedical Consultation Service at Brooks AFB in San Antonio, Texas were reviewed in order to answer the following questions:

- What are the most common psychiatric diagnoses given to aviators seen at the ACS?
- Are aviators more likely to be referred to the ACS-N at certain ages than others?
- Are aviators of different ages at increased risk for certain psychiatric diagnoses?

The ACS is a multidisciplinary aerospace medicine diagnostic center that has five primary missions. These are to:

- **provide aeromedical evaluations** to determine and assess the fitness of aviators and related personnel to ensure performance and safety in the aerospace environment.
- **provide training** in aerospace medicine and other areas or expertise through teaching, mentoring, or publication.
- **render expert opinion** on specific questions related to health, safety, and performance of aircrew and other mission-related personnel.
- **provide allied technology** or other services in response to specific USAF, US Department of Defense, allied, or related operational requirements.
- **conduct research** to advance aeromedical knowledge and to improve performance.

Current ACS-N staffing consists of one neurologist, two psychiatrists, three psychologists, and five technicians. Patients are seen in the ACS-N upon referral from flight surgeons throughout the USAF when there is concern they may have neurological or psychiatric conditions that can effect their medical qualification for flying duties. They are rarely seen if it is aeromedically clear from the outset that they cannot be returned to flying status. Patients whose flying qualification (from a neuropsychiatric standpoint) is relatively easy to assess are normally managed at their local medical facilities. Consequently, those seen in the ACS-N typically present diagnostic and disposition challenges. Thus, they may not be representative of aircrew with neuropsychiatric disorders throughout the USAF; this limits the generalizability of the findings of this paper. ACS-N evaluations typically are very comprehensive, multidisciplinary, and result in aeromedical recommendations concerning flying status.

Method

Records of all aviators referred to the ACS-N and receiving a psychiatric diagnosis during a six-year period (1993-1998) were reviewed (n = 481). Since there were few active duty subjects older than 50 years of age, only those under age 50 were included in this

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Table 1 Diagnosis Frequency

Diagnosis	N	% of sample
Reactive Disorders	80	19.7
Other Psychosocial Circumstances	62	15.2
Neurotic Disorders	54	13.3
Manic and Depressive Disorders	43	10.6
Special Symptoms	40	9.8
Alcohol Disorders	31	7.6
Family Problems	22	5.4
Personality Disorders	20	4.9
Psychic Factors Associate with Disease	20	4.9
Organic Disorders	19	4.7
Depressive Disorders NOC	16	3.9

study (n = 407). The sample was largely male (96.5 %), Caucasian (94.8%), officers (87%), and members of the USAF, Air National Guard, or Air Force Reserves (89.5%). Other organizations represented included the Army (n = 27), Army National Guard (N = 5), Army Reserves (n = 2). The mean age was 37.6 years with a 9.6 year standard deviation.

Psychiatric diagnoses included in this study are those which were given to at least 15 subjects and which may have a significant impact on their qualifications to remain on flying status. Sixteen ICD-9 diagnostic categories met these criteria. Additionally, certain diagnostic categories were combined when they involved similar kinds of disorders and when there were too few members in each individual diagnostic group to be useful, resulting in 11 diagnostic categories (see Table 1). The following nine categories were combined and labeled:

- Organic Disorders: Transient Organic Psychotic Conditions (293), Other Organic/Psychotic Conditions (294) and Specific Nonpsychotic Mental Disorders Due to Organic Brain Damage (311).
- Alcohol Disorders: Alcohol Dependence (ICD-9 303) and Nondependent Use of Alcohol (ICD-9 305).
- Special Symptoms: Physiological Malfunctioning Arising From Mental Factors (306) and Special Symptoms or Syndromes Not Otherwise Classified (307).
- Reactive Disorders: Acute Reaction to Stress (308) and Adjustment Reaction (309).

Subjects were divided into three age groups: 20-29; 30-39; and 40-49, representing early, middle, and late career stages. Data was analyzed using chi square tests and descriptive analyses.

Results

Question 1: What are the most common diagnoses given to aviators seen at the ACS?

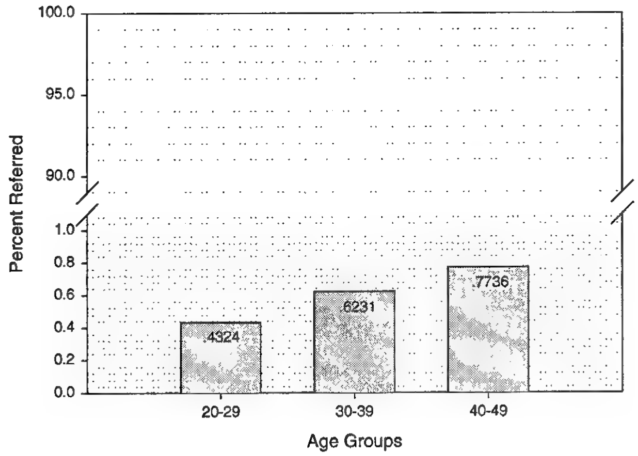
The frequencies with which specific diagnoses were given during the period of this study are noted in Table 1. As can be seen, Reactive Disorders (n = 80) was seen most frequently and represented 19.7% of all patients. Other diagnoses that were given to at least 10% of patients were: Other Psychosocial Circumstances (n = 62; 15.2%) (e.g. occupational maladjustment, interpersonal or phase of life problems), Neurotic Disorders (n = 54; 13.3%), Manic & Depressive Disorders (n = 43; 10.6%) and Special Symptoms or Syndromes Not Otherwise Classified (n = 40; 9.8%) (e.g. sleep disorders, anorexia, stammering, tics). Taken together, these five diagnostic categories made up over two-thirds (68.6%) of diagnoses given. The top three diagnoses found here are often considered to be non-disabling, and mild in traditional metal health practice. However, these diagnoses can be dangerous in occupations requiring rapid information processing and higher order cognitive skills such as in military flying. Those diagnoses commonly considered the most disabling in traditional mental health work were more rare in this sample (e.g., organic disorders, psychotic disorders).

Question 2: Are aviators more likely to be referred to the ACS-N at certain ages?

Figure 1 shows the percentage of all USAF active duty aviators between the ages of 20 and 49 who were given a psychiatric diagnosis by the ACS during the period of the study and broken into the three age groups. If the incidence of psychiatric diagnoses were proportional regardless of age, the percentages for all three age groups should be approximately equal, demonstrating no difference between the groups. The results suggest

Figure 1

Percent Referrals of Total Active Duty on Flying Status as a Function of Age Group



this is not the case. A chi square test was performed [chi square (2, N = 407) = 57.50, p <.0001] demonstrating that there are differences in the proportion of referrals across the three age groups. In particular, results suggest there is a greater percentage of referrals with increasing age. Research question 3 further evaluates this relationship.

Question 3: Are aviators of different ages at increased risk for certain psychiatric diagnoses?

This question was addressed through several methods. First, chi square analysis, using a diagnosis by age group frequency distribution (Table 2) was performed. This revealed a significant relationship [chi square (20, N = 407) = 52.64, p < .001]. It can be concluded, then, that diagnoses are not equally distributed across all ages. However, since there are no post-hoc tests for chi square analysis it is unclear where the distribution is unequal.

To further study this relationship the most frequent diagnoses were noted for each age group studied (see Table 2). What is apparent is that four diagnoses account for the top three diagnoses of each of the three groups studied. These are Reactive Disorders, Other Psychosocial Circumstances, Neurotic Disorders, and Special Symptoms or Syndromes Not Otherwise Classified. These are also among the five most common overall diagnoses noted in response to Question 1 (above). It appears, then, that while there may be some unequal distribution of diagnoses across the age groups, the most frequent diagnoses varied little among the groups studied.

Variability of diagnoses across the three age groups was also examined by looking at the percentage of members of each age group seen at the ACS-N who received each specific diagnosis (see "Difference" column in Table 2). The lowest percentage of referrals was subtracted from

Table 2 Percentage of Age Group By Diagnosis

Diagnosis	20-29	30-39	40-49	Maximum - Minimum Difference
Family Problems	2.3	5.8	6.8	4.5
Other Psychosocial Circumstances	24.7	10.5	15.9	14.2
Organic Disorders *	7.1	3.7	4.5	3.4
Manic and Depressive Disorders	9.4	10.0	12.1	2.7
Neurotic Disorders	10.6	14.7	13.9	4.1
Personality Disorders	8.2	6.8	0.0	8.2
Alcohol Disorders *	4.7	7.4	9.8	5.1
Special Symptoms *	14.1	11.0	5.3	8.8
Reactive Disorders *	18.8	19.5	20.4	1.6
Depressive Disorders NOC	0.0	2.1	9.1	9.1
Psychic Factors Associate with Disease	0.0	8.4	3.0	8.4

* combined diagnostic category

the highest percentage for each diagnostic category. A large difference score suggests the age groups differ in frequency with which their members received the diagnosis in question. For example, 2.3%, 5.8%, and 6.8% of the early, middle, and late career groups received the diagnosis of Other Family Circumstances. Subtracting the smallest from the largest percentage results in a percentage difference score of 4.5%. The most variability was for Other Psychosocial Circumstances (14.2%). Depressive Disorders Not Otherwise Classified (9.1%), Special Symptoms (8.8%), Psychic Factors Associated With Diseases Classified Elsewhere (8.4%), and Personality Disorders (8.2%) evidenced the next most frequent variability. Therefore, in relation to the other findings associated with research question three, we conclude that there is a tendency for certain disorders to be associated with different age groups.

Conclusions/Discussion

Given the study limitations mentioned above such as potential sample selection bias, results of this study revealed that five psychiatric diagnoses account for the majority of the psychiatric diagnoses given aviators at the ACS-N regardless of career stage. These diagnoses are Reactive Disorders, Other Psychosocial Circumstances, Neurotic Disorders, Manic and Depressive Disorders, and Special Symptoms. The top three diagnoses are considered mild, least disruptive to lifestyle, and usually not disabling in the general population. People with these diagnoses are most often treated as outpatients with brief psychotherapy and/or classes of psychotropic medication that are short acting. However, in demanding occupations such as military aviation, these diagnoses may represent the bigger threat just because these conditions appear not to interfere with daily living and can be denied or actively hidden. Further, while many of the other psychiatric diagnoses are obviously disabling, these "reactive," "neurotic" diagnoses are aeromedically disabling specifically in psychological areas critical to aviation: memory, attention-concentration, reaction time, speed of information processing -- that is, the higher cortical centers and resulting skills

Secondly, these results indicate that psychiatric disorders are not proportionately distributed throughout all three age groups. Generally speaking, there appears to be a positive relationship between age and probability of receiving a psychiatric diagnosis; younger aviators are less likely to have such a condition than older ones.

Finally, in this study diagnoses are not distributed evenly nor randomly across all age groups. These differences appear to be fairly subtle but may be significant. Other Psychosocial Circumstances and Personality Disorders were diagnosed more frequently in early career aviators than those in the middle and late stage of their careers. Psychosocial circumstances that result in an aviator being seen for an ACS-N evaluation often involve adjustments to the aviation environment. This is more likely to be an issue early in an aviator's career since the problem either subsequently resolves or aviators with these problems are eliminated from flying. Similarly, aviators with personality disorders may present with behaviors that are incompatible with flying safety and mission completion; such conditions are likely to be identified early in an aviator's career and dealt with administratively. On the other hand, a comprehensive physical examination is required prior to beginning aviation duties. Consequently, it would be expected that early career fliers are infrequently seen for Psychic Factors Associated With Diseases Classified Elsewhere, and this appears to be the case. However, disease or injury becomes more likely later in an aviation career and this is consistent with the findings of this study. Mid-career aviators had this diagnosis most frequently. Finally, the late-career aviator group had more members with atypical depressive disorders than those earlier on. This could be the result of with preparation to leave military flying careers and adapting to civilian life, discomfort with increased levels of responsibility associated with increased rank, and other phase of life problems.

This study was designed to further knowledge of mental health issues confronted by aviators and their flight surgeons. These findings indicate that most common psychiatric problems encountered in this aviator group were reactive and stress related. Thus, one possible association for further evaluation is the role stress models (e.g., Selye) may play in age related psychiatric disorders. In aerospace psychiatry and psychology examiners often search for the answer to "why now" with the notion that a specific stress or occurrence related to the disorder might indicate a positive prognosis after effective treatment. These results might suggest, much as stress theories indicate, that small, incidental but regular stressors are associate with a variety of diseases (in this case psychiatric disorders) across time. These heuristic findings require further study, but if substantiated, could lead to clearer, more effective aeromedical decisions. Further, in this sample these top three most frequently seen disorders were generally evenly distributed across the three age groups except for the "other Psychosocial Problems" which were higher for younger and older aviators. Future research should further evaluate these findings and also identify significant stresses that may adversely effect the aviator in an effort to lessen these effects.

An understanding of the frequency and selectivity of psychiatric disorders among aircrew and as related to career stage may help flight surgeons identify precipitating stresses in fliers and initiate early intervention that may avoid the loss of valuable crew.

Anthrax Immunization in the Older Warrior

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Summary: When a higher than expected prevalence of adverse reaction was apparent following the first immunization, it was decided to monitor acceptance, adverse reactions, incapacity and antibody responses in 129 mainly caucasian members of a military field hospital during a voluntary programme of anthrax immunization at 0, 3, 6 and 24 weeks. Attempts were made to relate these variables to age. It was found that older warriors were at least as likely as younger colleagues to complete a voluntary anthrax immunization programme. They did not report adverse reactions more frequently at any stage but if an adverse reaction did occur following the first immunization, significant incapacity (inability to lift or to drive) lasting 48 hours in the majority occurred more frequently. There was no evidence that increasing age resulted in a diminished antibody response to anthrax immunization. The only penalty related to age appeared to be the higher prevalence of incapacity if adverse reaction followed the first anthrax immunization. This could be particularly critical in certain more vulnerable military populations such as aviators if a substantial proportion of personnel were over the age of 30 years and were possibly immune but were considered to require an urgent programme of anthrax immunization before deployment.

Introduction

Background

The potential for anthrax spores to be used as a biological weapon has been reviewed recently[1]. A previous study suggested that up to 1300 spores could be inhaled by human beings over 8 hours with little probability of adverse effect[2] but once a threshold (c. 4-80 x 10^3 spores in sub-human primates over periods varying from a few minutes to a few days) was exceeded[3] a high proportion of those exposed would develop fatal pulmonary anthrax[4] unless some form of effective preventive measure was taken. Experiments in primates exposed to supralethal doses of inhalational anthrax have indicated that while antibiotics may provide good short term protection, immunization is the preferred method to provide long term protection[5]. This could be especially important in older warriors. Less efficient memory may compromise antibiotic chemoprophylaxis and a lower threshold for physiological and psychological degradation may exist when individual protective equipment has to be worn. Attack with a persistent biological weapon such as anthrax may present an even greater challenge to older personnel if the likelihood of completing a voluntary immunization programme was less, the prevalence of side effects and resulting incapacity from anthrax vaccine were greater and the production of antibody was impaired.

Voluntary immunization

One hundred and twenty-nine mainly caucasian members of a military field hospital, alerted for possible immediate deployment to an operational theatre where there was a high probability of attack with anthrax spores, were listed to receive a schedule of intramuscular immunizations with anthrax vaccine at 0, 3, 6 and 24 weeks, commencing in March 1998. Owing to concern expressed by veterans of the Gulf War 1990/1991 that, amongst other immunizations, anthrax vaccine could have been responsible for the so-called "Gulf War Syndrome", immunization on this occasion was voluntary at all stages. Nevertheless, acceptance of immunization by a military medical unit could reasonably be expected to be higher than other units on account of the nature of the personnel involved and their potentially higher risk of exposure to any casualties with anthrax.

Anticipated prevalence of side effects

British anthrax vaccine consists of an alum-precipitated cell-free filtrate of a culture of the Sterne strain of *Bacillus anthracis*, preserved with thiomersal. Based on reports of adverse reactions to this vaccine to the Committee on the Safety of Medicines and that a potential total of 516 doses of anthrax vaccine would be administered (see reference 6 for further details), only one or two subjects were expected to complain of symptoms resulting from a possible adverse reaction. When several members of the unit who had not attended sick parade mentioned having had possible adverse reactions to anthrax vaccine, a study was rapidly devised to elicit reports of possible adverse reactions and any relation to the immune response following each immunization.

Present study

The overall acceptance of immunization, prevalence and severity of adverse reaction and any associated

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incapacity at each stage of the immunization schedule have been reported previously[6]. The present study examines the relationship between these variables and age of vaccinees and also reports, for the first time, the age-related aspects of the immune responses.

Methods

Full details of surveillance methods have been reported previously[6]. Briefly, personnel attending for re-immunization at 3, 6 and 24 weeks and also at 32 weeks were provided a questionnaire which requested personal details; details of any previous anthrax immunization before the current series; the nature and severity of any adverse reaction and any associated incapacity. Those subjects who failed to attend for subsequent immunization were located wherever possible and sent a questionnaire by post for completion and return. In order to monitor the immune response and to examine any relation between this and occurrence of adverse reaction, a 5ml blood sample was requested and, subject to written informed consent, taken and serum was separated and stored at -80° Celsius for later enzyme-linked immunoabsorption analysis of IgG antibodies produced to protective antigen.

Statistical analysis

When sample variances were homoscedastic by F-test, the significance of differences between two mean values was assessed using Student's *t*-test and otherwise by Mann-Whitney U-test. The significance of differences in mean values of three or more groups was assessed by one-way analysis of variance. The significance of differences in proportions in contingency tables was assessed by χ^2-test or Fisher's exact test as appropriate. Where trends were suspected in contingency tables, χ^2-test for trend was applied. Statistical significance was considered to exist in all circumstances when $p<0.05$.

Results

Previous findings

Briefly, it was found previously[6] that

a) follow-up was acheived in 85% of subjects

b) an initially high (76% of subjects) acceptance of immunization dwindled significantly ($p<0.0001$) to 22% at 24 weeks

c) the prevalence of adverse reaction dwindled significantly ($p<0.0001$) from an initial 63% of vaccinees to 25% at 24 weeks

d) there was no evidence that adverse reactions, their nature or severity or associated incapacity prevented acceptance of subsequent immunizations

e) the proportion of those who had received anthrax immunization 7 years previously or who were officers who experienced adverse reactions after the first immunization was increased

f) there was no increasing prevalence of adverse reaction with increasing age quartile after the first immunization and, hence, older age could not account for an increased prevalence of adverse reactions in officers

g) the distribution of adverse reactions was the same at all stages of the immunization schedule with 47% experiencing a local reaction (mainly pain at the injection site), 24% experiencing systemic (mainly influenza-like) reactions and 27% experiencing both

h) the prevalence of incapacity (45%) amongst those who experienced adverse reactions was the same at all stages of the immunization schedule

i) Total IgG antibody to protective antigen was generally higher at all stages of immunization in those who had been immunized to anthrax previously.

Acceptance of immunization

The mean age of personnel accepting immunization at 6 and 24 weeks was statistically significantly different ($p=0.002$ and $p=0.028$ respectively) being greater than those failing to receive immunization at these times (Table 1) and there was a statistically significant trend (χ^2 for trend=7.78, df=1, $p=0.005$) towards a greater proportion of subjects accepting immunization at 6 weeks with ascending age quartile (Table 2). No age-related differences in relation to acceptance of immunization were found at other times.

Stage of anthrax immunization	0 weeks	3 weeks	6 weeks	24 weeks
Mean age (yrs±SD) of those accepting (N, n)	31.8±6.6 (98, 95)	31.6±6.3 (78, 73)	**34.1**±6.6 (41,41)	**34.3**±7.0 (28, 28)
Mean age (yrs±SD) of those *not* accepting (N, n)	30.7±6.0 (31,20)	31.7±6.3 (56, 42)	**30.4**±5.7 (88, 74)	**31.3**±6.0 (101, 87)
p	NS	NS	**0.002**	**0.028**

Table 1. Mean ages of those accepting and not accepting anthrax vaccine at each stage of the voluntary immunization schedule. N=number of personnel, n=number of personnel for whom ages were known. NS=not significant.

Age quartile	1 (19.8-27.0yrs)	2 (27.4-30.6yrs)	3 (30.7-34.3yrs)	4 (≥34.4yrs)
Number *(%)* accepting immunization	5 *(18%)*	9 *(31%)*	12 *(41%)*	15 *(52%)*
Number *(%) not* accepting immunization	23 *(82%)*	20 *(69%)*	17 *(57%)*	14 *(48%)*
Total	28	29	29	29

Table 2. Numbers for whom ages were known accepting and *not* accepting anthrax immunization at 6 weeks according to ascending age quartile (χ^2 for trend=7.78, df=1, p=0.005).

Adverse reactions

No statistically significant difference in mean age was found between those reporting and those not reporting adverse reactions at any time (Table 3) nor was there any significant trend for the proportion of those reporting adverse reactions to increase with ascending age quartile at any stage in the immunization schedule (data not shown).

Stage of anthrax immunization	0 weeks	3 weeks	6 weeks	24 weeks
Mean age (yrs±SD) of those reporting an adverse reaction (N, n)	32.3±6.6 (62, 62)	33.5±6.6 (14, 14)	33.7±6.4 (14, 14)	33.9±5.1 (7, 7)
Mean age (yrs±SD) of those *not* reporting an adverse reaction (N, n)	30.7±5.8 (36, 33)	31.2±6.2 (59, 59)	34.3±6.8 (27, 27)	34.3±7.6 (21, 21)
p	NS	NS	NS	NS

Table 3. Mean ages of those reporting and *not* reporting adverse reactions at each stage of the voluntary anthrax immunization schedule. N=number of personnel, n=number of personnel for whom ages were known. NS=not significant. There was no significant trend for the proportion of those reporting adverse reactions to increase with ascending age quartile at any stage in the immunization schedule.

Incapacity

The mean age of those who experienced incapacity was slightly but significantly greater than that of those who were not incapacitated as a result of adverse reaction following immunization at 0 weeks (34.2yrs vs 30.7yrs; p=0.037; Table 4) and there was a statistically significant trend (χ^2 for trend=5.61, df=1, p=0.02) for the proportion incapacitated as a result of adverse reaction to increase with ascending age quartile at 0 weeks (Table 5) but no difference was found at other times. In general, the incapacity (inability to lift, inability to drive) was significant (and could have greater significance in military occupational groups other than hospital personnel) and had resolved within 48 hours in the majority (63%) of incapacitated subjects. All incapacities had resolved by 5 days.

Stage of anthrax immunization	0 weeks	3 weeks	6 weeks	24 weeks
Mean age (yrs±SD) of those reporting incapacity (N)	**34.2**±6.8 (28)	30.2±5.1 (6)	32.0±6.1 (6)	33.4 (3)
Mean age (yrs±SD) of those *not* reporting incapacity (N)	**30.7**±6.0 (34)	35.9±6.8 (8)	35.0±6.7 (8)	34.3 (4)
p	**0.037**	NS	NS	-

Table 4. Mean ages of those who reporting and *not* reporting incapacity in consequence of adverse reaction to anthrax immunization

Age quartile	1 (19.8-27.0yrs)	2 (27.4-30.6yrs)	3 (30.7-34.3yrs)	4 (≥34.4yrs)
Number *(%)* reporting incapacity as a consequence of adverse reaction	4 *(29%)*	5 *(28%)*	7 *(70%)*	12 *(60%)*
Number *(%) not* reporting incapacity as a consequence of adverse reaction	10 *(71%)*	13 *(72%)*	3 *(30%)*	8 *(40%)*
Total	14	18	10	20

Table 5. Numbers reporting incapacity as a consequence of adverse reaction to anthrax immunization at 0 weeks according to ascending age quartile (χ^2 for trend=5.61, df=1, p=0.02).

Antibody responses

As total IgG antibody level to protective antigen was generally higher at all stages in those who had received anthrax immunization 7 years previously, examination of antibody responses in relation to age was confined to naive subjects. No correlation was found between antibody concentration and age at 3 weeks and 24 weeks following immunization at 0 and 6 weeks respectively. The results of attempted rank correlation at 3 weeks (which were very similar to those obtained at 24 weeks) are shown in the figure.

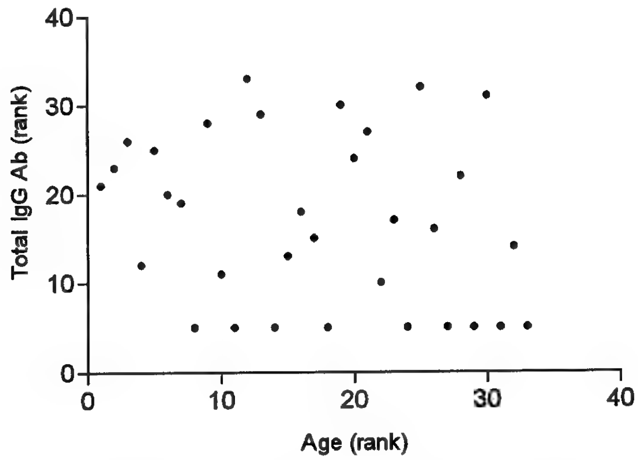

Figure. Rank correlation: Total IgG antibody to protective antigen *versus* age *circa* 3 weeks following initial anthrax immunization in naive subjects (n=33; Spearman's r= -0.2, p=0.2).

Discussion

Operational consequences

The present study has shown that older personnel are at least as likely as younger colleagues to complete a voluntary anthrax immunization programme suggesting that motivation is not impaired with increasing age. They did not report adverse reactions more frequently but were more likely to suffer attendant incapacity following the first immunization if they were over 30 years of age. Units having a high proportion of such personnel could be less immediately effective in the event that operational requirements demanded rapid anthrax immunization, especially if re-immunization of potentially immune subjects was deemed necessary given that previously immunized personnel were found more likely to experience adverse reactions on re-immunization. The duration of this incapacity is limited to about 48 hours in the majority of affected subjects but there are many special circumstances when this could be particularly critical. For example, military aviators operating from bases confronted suddenly by the risk of attack with anthrax could suffer a significant temporary potential reduction in operational capability if immediate immunization against anthrax was considered essential.

Previous studies of immune responses in civilians

It was reassuring that immune response to anthrax vaccine was at least as good in older military subjects as their younger colleagues. A number of host factors are known to affect immune responses[7]. In the present study, all of the subjects were in good health with no past history of recurrent infection which might indicate congenital immune impairment. None of the female personnel were pregnant. All had to have passed medical examinations for enlistment or commissioning. Satisfactory routine military medical re-examination and bienniel physical fitness assessments were necessary for continuing military service. All were well-nourished. No specific enquiry was made about cigarette smoking or alcohol consumption. However, the impression gained was that there was a lower general prevalence of cigarette smoking than in other military units but there may have been some preponderance in younger personnel who also tended to drink more alcohol. Therefore, immune responses were unlikely to be impaired, particularly in older military personnel, by such general host factors identified in studies of civilians. However, older adults generally have less effective immune responses to invading organisms than younger adults. Studies of the age-related immune responses to viruses and viral proteins rather than bacterial toxins appear to predominate in the recent literature. After taking the presence of haemophilia into account, there was found to be a strong inverse relationship between increasing age and survival in adult haemophiliacs infected with human immunotrophic virus-1 which, whatever the mechanism involved, betokens an age-related reduced ability to combat infection[8]. Mechanisms have been more closely examined in relation to immune responses to influenza virus. Although pre-immunization antibody titres to influenza virus haemagglutinin or neuraminidase were generally lower in younger adults than older subjects, the former had almost double the antibody production response of the latter following immunization with inactivated influenza virus[9, 10]. The defective antibody production in the older adult appeared to be primarily IgG1 subclass whereas IgG3 production was unaffected by age[11]. Recognition of the influenza virus does not

appear to be a problem as the proliferative response of cytotoxic T-lymphocytes was found to be similar in different age groups whereas lysis of virus-infected autologous cells was impaired in older subjects[12, 13]. Similar age-related impairment in antibody production has been found in response to hepatitis B vaccine in patients with chronic renal failure which was independent of the effect of severity of disease although this was also found to attenuate antibody responses[14]. In relation to bacterial toxins, adults over the age of 60 years have impaired immune response to the less immunogenic type 6B pneumococcal polysaccharide following intramuscular injection of pneumococcal vaccine when compared with adults under the age of 45 years[15]. In contrast, immune responses to an oral cholera vaccine were unaffected by age[16].

Immune response in the military population

The general tendancy for poorer immune response to occur in older subjects was not found in relation to anthrax immunization in military personnel. Had any statistical difference been found, the clinical significance could still have remained questionable as small differences in antibody concentration may not necessarily indicate much difference in resistance to disease. Studies of the protective effect of various anthrax vaccines in experimental animals subsequently challenged by intramuscular injection of various strains of anthrax spores with varying virulence have shown a poor relationship between antibody concentration and protection. Nevertheless, it is generally acknowledged that at least some detectable antibody is required in animals for any protection[16, 17, 18]. Similarly, no relationship was found between development of antibodies to influenza virus neuraminidase which was impoverished in older adults and the ability to inhibit neuraminidase which was similar in the young and old[10].

Conclusion

Older warriors are at least as likely as younger colleagues to complete a voluntary anthrax immunization programme. They do not report adverse reactions more frequently at any stage but if they do experience an adverse reaction following the first immunization, significant incapacity occurs more frequently lasting not more than 48 hours in the majority of subjects. There could be particular military circumstances where this is critical if operational capability is compromised significantly in the short term. While the clinical relevance is uncertain, there is no evidence that increasing age results in diminished antibody response to anthrax immunization.

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GROWTH HORMONE AND AGING

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Introduction

Growth hormone (GH) is a peptide containing 191 aminoacids that is secreted by the acidofilic cells of the pituitary and has a very important action on growth during infancy and adolescence (Devesa et al 1996). To perform this action GH needs the collaboration of a full series of factors such as, thyroid hormones and sexual hormones together with an appropiate nutrition.
GH is under the hypothalamic control of two peptides, one stimulating, GHRH firstly discovered in 1.982 (Guillemin et al 1982, Rivier et al 1982), and another inhibitory, somatostatin, that is a tetradecapeptide, discovered in 1973 by Brazeau et al (1973).
Interaction between GHRH and somatostatin plays a significant role in the secretion of GH and somatostatin seems to play the major role (Devesa and Tresguerres 1996). GHRH is secreted in peaks as well as somatostatin, both with 180° shift, so that the GH peak appears when GHRH levels are high, and somatostatin levels are low. GH disappears from blood when somatostatin values are high in the hypothalamus and GHRH is low (Tanenbaun and Link 1983). This control is exerted so that GH is secreted every 3h. approximately, with higher amplitude during the night, actually during slow wave sleep.
Some of the actions of GH are exerted through an intermediary product, IGFI, that it is synthetized in the liver and in other tissues under the estimulation of GH (Tresguerres 1996)
IGFI is a peptide of 70 aminoacids that shows similarities with proinsulin and acts on a paracrine way on the growth plates of the long bones stimulating the multiplication of chondrocites and determining growth. IGF I generated in the liver under GH stimulation circulates in the blood bound to a series of transport proteins called IGF BPS that are also GH dependent, especially IGFBP 3. However the most important role is exerted by this a peptide, when sinthesized locally in a paracrine way (Tresguerres1996).

Aging as a model of GH deficiency.

GH stimulates growth when given to children or adolescents as substitution therapy to treat is deficiency so that children are capable of reaching a normal stature if treated conveniently and starting from a very young age (Casado de Frias et al 1996). The therapeutical use with GH started in 1957 (Raven et al 1957) and from that time on an evident beneficial action of GH therapy has been obtained in those patients. However when those children reached puberty and the growth plates became closed, GH therapy was discontinued since it was considered as not playing afterwards any significant role in the body.

However when a very broad study was performed some years ago, investigating the evolution in the adult age of those patients that were treated as children with GH, a significant number of problems were detected that included an abnormal composition of the body, with increase in central fat and muscular weakness with a reduction in bone density, fatigue and reduction of the subjective sensation of well being (Sassolas 1994). In adition an increase in cardiovascular mortality, has been detected (Rosen and Bengtsson 1990, Bates et al 1996). All this facts make evident that GH is also important in a full series of vital functions in our body also after final height has been achieved.
The aging process in man is associated with a reduction in muscular and bone mass together with an increase in body fat (Forbes 1976). Aged people show very reduced GH and GFI values in plasma as compared to young individuals (Toogoot, and Colls 1996), so that the observed metabolic changes have been correlated with body composition and the reduction of GH and IGFI levels, starting to speak about the existence of a true "somatopause" (Hoffman et al 1993). All these processes are evident after sixty years of age, so that aging itself could be considered as a form of "GH deficiency". Old people show muscular atrophy, an increase in central fat together with osteoporosis and a reduction in the immunological competence, so that neoplastic processes are favoured (Iglesias et al 1996). All

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these changes can be influenced by the exogenous administration of GH, since the substitution therapy with this hormone stimulates muscular development, induces loss of fat tissue and enhances bone density (De Boer et al 1995, Gibney et al 1999).

The mechanisms that could play a role in the reduction of the GH associated with age have been thoroughly investigated and the following ethyologies are possible: 1) Reduction in hypothalamic GHRH, 2) An Increase in somatostatin secretion, 3) Reduction in the number of somatotrophic cells in the pituitary, 4) Increase the sensitivity to the negative feed back of IGFI.

The majority of papers agree that the principal alterations during somatopause should be located in the hypothalamus. A reduction in GHRH secretion (Ono et al 1986, De Gennaro Colonna et al 1989) and/or an increase in somatostatinergic activity (Locatelli et al 1984) seem to be responsible for the appearance of very low plasma GH levels during aging.

Another important fact that needs to be taken in to account is, that GH secretion is dependent of slow wave sleep (Van Cauter and Plat 1996). During aging a reduction in this type of sleep has been detected. This is probably motivated by a reduction of the nocturnal melatonin secretion (Copinschy y Van Cauter 1995), that could play also a role in GH disminution.

Substitution teraphy of GH deficiency during aging.

Since the important work performed by Rudman et al (1990), it has been demonstrated that treatment with GH, in old people can exert a very positive role in the reduction of hormonal and metabolic changes associated with aging. GH administration to men older than sixty years of age is capable of restoring IGF I levels to aproximately those appearing in young persons including an increase in muscular mass, bone density and the reduction in the percentage of body fat (Rudman et al 1990, Holloway et al 1994, Cuttica et al 1997). Adverse side effects can appear if the treatment is prolonged and high dosages of GH are used, but always those secondary effects are of minor entity. When low doses of GH were used for a periode of 10 years of treatment side efects were nearly absent (Gibney et al 1999).

Experimental studies have been performed in rats, that were treated over small periods of time, always lower than fifteen days, showing the same positive effects observed in men (Cartee et al 1996): increases in muscular mass and in heart weight (De Gennaro, Colona y Colls 1993).

Effects on muscular system

Physiological aging shows a reduction in lean body mass with an increase in body fat that is associated with a reduction in the capacity to perform exercise and also leads to cardiovascular alterations especially by the existence of hyperlipidemia (Rosen and Bengtsson 1990).

These changes are similar to those appearing during GH deficiency (Rosen et al 1993). In all those cases treatment with the biologic synthetic GH increases basal metabolism (Van Wyck et al 1988) with the establishment of a positive nitrogen balance (Valk et al 1994) due to an enhancement of aminoacid absorption in the digestive system (Copeland and Nair 1994). This also stimulates protein synthesis and leads to an increase in muscular mass (Juul 1996), in physical strength (Jorgensen et al 1991) and to the normalization of lean body mass (Salomon et al 1989).

Effects on the cardiovascular system

GH has been shown to increase cardiac function (Amato et al 1993), increasing left ventricular mass and left ventricular output (Valcavi et al 1995). As a consequence, there is an increase in the capacity to perform exercise with an increase in oxigen consume (Nass et al 1995). Carotid intima thickness was also reduced (Gibney et al 1999).

GH administration reduces cholesterol levels (Weaver et al 1995), redistributing and reducing body fat and this leading to a reduction in cardiovascular risk.

Substitution therapy with GH has a beneficial effect inducing a lipolitic action on the adipocites and establishing a better relationship HDL / LDL cholesterol (Beshyah et al 1995 and Angelopoulos et al 1998). All these effects are maintained also when the treatment is maintained for long periods of time. Jorgensen et al (1994) have shown patients treated for more than three years without the appearance of important secondary effects and Gibney et al (1999) for more than 10 years so that recently the treatment of the dilated cardiomiopaty with GH has been proposed (Osterziel et al 1998) as well as other cardiac diseases.

Actions on the bone

One of the problems that has direct incidence on the quality of life of aged patients is the reduction of bone mass. This problem is more evident in the woman and can be, at least partially

prevented in those, with the substitution therapy with sexual hormones after menopause. The reduction in bone mass can very markedly limit motility and can also generate pathologies that are potentially very serious, like hip fractures and vertebral crushing (Iglesias et al 1996).
GH administration increases calcium, phosphate and osteocalcin levels in plasma. Under GH deficiency there is a reduction in mineral bone density (Dagerblad et al 1995) similar to what happens during aging. Treatment with GH is capable of increasing bone turnover. Thus the rationale for treatment of bone problems with GH seems logical. In the case of women, this treatment can be associated with sexual steroids (Holloway et al 1994), potentiating the beneficial effects of those. In experimental studies GH increases Calcium absortion in old rats and both GH, IGF I are capable of stimulating directly the osteoblastic activity (Kassem et al 1993), so GH treatment is capable of increasing bone mass in patients with GH deficiency (O'Halloran et al 1993).

Experimental studies

Experimental studies performed in our laboratory, using aged rats showed that the daily administration of GH to animals of 24 months of age elicited beneficial effects in the same way as those seen in humans. Animals treated during one month with 2 UI of GH subcutaneously twice a day showed and increase in muscular mass, with an increase in lean body mass, and a reduction of body fat. IGFI levels were increased as well as osteocalcin whereas alcaline phosphate was reduced. Blood cholesterol was not modified but free fatty acids were increased as a result of lipolisis.

Effects on the quality of life

Hipotituarism is associated with higher cardiovascular mortality (Rosen and Bengtson 1990, Bates et al 1996). In the old population, higher cholesterol and trigliceride levels are present, with an increase in central body fat, that is related to cardiovascular risk. Substitution therapy with GH leads to a significant reduction of those parameters (Rosen et al 1993, Gibney et al 1999), together with an increase in physical capacity (Jorgensen et al 1991) and a better cardiac performance (Amato et al 1993). This is associated with an increase in the sense of well being.

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ENDOCRINE RESPONSE TO TRAINING PROGRAMS IN THE MIDLIFE

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SUMMARY

It has been proposed that regular physical exercise training could delay the normal process of aging and protect against the metabolic disorders of midlife. In order to relate the hormonal response to training and its protective effects, the recent theory on aging are firstly exposed. The role of hormonal changes on aging process is evoked. In the second part, the normal hormonal response to physical exercise and training, are exposed. In the last part, the specificity of hormonal response to training in midlife is used to explain some protective effect of training. The principal effect seem the improvement in insulin sensitivity but the role of training on growth hormone and androgen could be involved in the effect of training on muscle mass and bone density.

Key words : Hormonal response to training - Ageing process - Midlife - Insulin sensitivity - Growth hormone - Androgens.

RESUME

Il a été suggéré que l'entraînement physique régulier peut retarder les processus du vieillissement et protéger contre les désordres métaboliques de l'âge moyen.

Dans le but de mettre en relation la réponse hormonale à l'exercice musculaire et ses effets protecteurs, la première partie de cet exposé est un rappel sur les théories récentes du vieillissement. Le rôle des hormones sur les processus du vieillissement est évoqué ensuite. Dans la seconde partie, la réponse hormonale à l'entraînement est exposée. Dans la dernière partie, la spécificité de la réponse hormonale à l'entraînement est utilisée pour expliquer les effets protecteurs de l'entraînement sur le vieillissement. L'effet principal semble être l'augmentation de la sensibilité à l'insuline. Mais le rôle de l'entraînement sur les androgènes et l'hormone de croissance peut être évoqué pour expliquer les effets de l'entraînement sur la masse musculaire et la densité osseuse.

INTRODUCTION

Continuation of physical training in midlife is of major epidemiological interest. The question is to know how far physical training is able to prevent ageing processes which start at midlife. To provide some answers to this question we will successively review the ageing theories and consequences of ageing on the energy metabolism and supporting tissues, and the influence of hormones on this process. Using this data, we will compare the hormonal response to training of young and older subjects ; we will try and define relationships between the hormonal response to physical training and protection against the ageing process.

1. AGEING PROCESS

Current knowledge on the ageing mechanism has been comprehensively reviewed by Treton and Courtois (24). While we are totally unaware of it, a continuous biological process, senescence, takes place as soon as we are born and constantly changes the structure and operating process of our organism. This process takes place at a rate and according to patterns which are different for various categories of cells, tissues and organs. It concerns all strata of living matter, from the simplest molecules to the most sophisticated control systems.

Two families of theories, not necessarily contradictory, have attracted the attention of gerontologists over these past twenty years, one implying that ageing is an unpredictable (stochastic) phenomenon, the other defending the idea that ageing is programmed. These theories rely on the general concept that each organism has its own quota of life to live and will age and die as a function of the use made of this quota. Numerous experiments have been run to

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try and modify this quota by various factors : temperature, caloric restriction, physical training. In cold-blooded animals it is possible to shorten or prolong life-span by modifying temperature as this factor has a direct effect on their metabolism. In mammals, we observe that small species (rats, mice) which have a high metabolism, live a short time whereas larger species (cows, horses) with a lower metabolism live longer.

Numerous experiments on diet restriction in mice and rats showed longer life-span, and reduced decline in the immune system associated with ageing. In certain cases it reduced the incidence of certain diseases including cancer.

Physical training has recently been recommended as a cure to improve health and prolong life (11). Life expectancy of laboratory rats is increased if regular moderate physical training (equivalent to jogging in man) is started in early life and always continued. However, too few long term investigations have been performed in man to give such results a general value. Regular exercise improves performance of the heart and lungs, reinforces bone strength , and prevents cardiovascular diseases. But the effects of physical training on life-span are still unknown. Several factors influenced by physical exercise may act upon ageing. Free radicals, generated by muscular effort can react with many biological molecules (fatty acids, DNA, proteins). Modified lipids (peroxide) alter the structure of biological membranes, causing a rupture of lysosomes, releasing the peroxidized or undegradable polymerized elements which can ultimately promote ageing.

Hormonal and immune phenomena resulting from physical exercise could act upon an internal clock or pace maker controlling ageing. There are two major categories of pace maker : in one, the pace maker is connected to the brain, more specifically to neuro-endocrine control on the anterior hypophysis ; in the other the pace maker is connected to the thymus or immune system.

1.1. Pace maker hypothesis

Pacemaker connected to the hypophysis

The hypophysis is a gland which plays a key role in the life cycle of vertebrates (growth, sexual maturity) by its neuro-hormonal control. It has been shown that underfeeding depresses the anterior function of the hypophysis, delays maturation and prolongs life-span. A substantial increase in life-span is thus observed in rats which were hypophysectomized in early life and administered a treatment of corticoids. The ageing rate of collagen, kidneys and immune system of these animals is lower, and the incidence of vascular diseases is also reduced.

Pace maker connected to the thymus and immune system

This system changes during maturation and ageing and could play the role of ageing pace maker. This would result in a decline in T immune control and growing self-immunity. There is no doubt that changes in the T immune system take place during ageing and play a role in certain age related diseases (rheumatisms). However, the question is to know how far this immune phenomenon acts as causal agent of ageing. We will see later how it is possible to relate the hormonal response to physical exercise with its influences on the thymic and immune systems.

1.2. Metabolic and degenerative diseases associated with ageing

Aside from unavoidable programmed cell death, a number of diseases occurring at midlife may accelerate the ageing process. The high epidemiological prevalence of cardiovascular and metabolic diseases placed them at the forefront of investigations. It has been unequivocally shown that the normal ageing process is associated with enhanced resistance to insulin, partly considered as the cause of increased concentrations of circulating lipids and, particularly, very low density lipids (VLDL). This increase is associated with a gradual elevation of insulin concentrations in rats fed ad libitum (1). In rats restricted feeding increases life-span, this increase being associated with depressed insulinemia and circulating lipid concentrations (14). This data supports the idea that initial variations in sensitivity to insulin are the cause of changes in circulating lipid concentrations. The effect of physical training on prevention of metabolic diseases mostly results from the effects of physical exercise on the mechanism of insulin.

A decrease in the levels of insulin and an increase in the consumption of glucose are observed during physical exercise. Considering the role of insulin in the penetration of glucose into the muscle, this phenomenon may appear to be a paradox. However, this apparent contradiction disappears if we take into consideration the fact that exercise enhances glucose transportation into muscles. This phenomenon occurs at low insulinemia, but not if it is null. It is partly associated with a significant increase in sensitivity to insulin during physical exercise. Physical training makes this effect durable and permanently increases sensitivity to insulin. This plays a key role in metabolic changes induced by physical exercise. The study of animal models shows enhanced glucose transfer under the effect of the same concentration of insulin on rat muscles after three weeks of training (6)(Fig. 2). The mechanism of this enhanced sensitivity to insulin is associated with a reinforced insulin-

receptor binding, and also with an increase in the tyrosine kinase activity at the post-receptor stage. These studies on animals explain the effects of physical training observed on healthy man. Recent research by Sato et al. (21) using the insulin clamp showed a substantial increase in sensitivity to insulin in trained subjects compared to sedentary subjects.

However, another hormonal factor could be suggested to explain the effects of physical training on metabolism. Recent results by Rivière et al. (19) show that lypolysis induced by increasing concentrations of adrenaline is higher in preparations of adipocytes sampled from trained women, which shows that sensitivity to catecholamines increases under the effect of physical training. Several results indicate enhanced metabolization of lipids depending on the activation of enzymatic systems such as muscle lipoprotein lipase activity. This system is activated by plasma catecholamines. Such actions, combined with the various levels of lipid metabolism explain the difference in lipid concentrations in sedentary and trained subjects. The comparative study by Martin et al. (13) on changes in lipid concentrations as a function of three levels of physical activity indicates a decrease in cholesterol and triglycerides and a higher HDL fraction. Such results can be associated with the enhanced sensitivity to insulin and catecholamines resulting from physical training.

1.3. Effect of ageing on support tissues

The involution of support tissues, bone and muscle, which gradually takes place with ageing is a real problem as it influences the motor activity of the aged. In this review we will use data obtained from immobilization protocols as the reduction in activity is one of the main factors causing a shrinkage of muscle mass in ageing subjects. Ageing processes reduce muscle mass and contractility (12). This muscular atrophy is associated with a preferential decrement in the number of fast twich fibers. Physical training is capable of reducing muscular atrophy caused by ageing (2)(Fig. 3). We will use current knowledge of the role of hormones on the trophicity of muscle tissue to suggest hypotheses on the protective role of physical training through hormonal responses. The main hormones which can act upon muscles are androgens, glucocorticoids, thyroid hormones, and growth hormone.(GH).

1.4. Hormonal changes with ageing

Androgens

Numerous studies have shown that androgenous steroids have an anabolic effect. The histological analysis of this phenomenon shows that the increase in muscle mass results from an increase in the number of non contractile proteins. Administration of testosterone to immobilized rats prevents weight loss in postural muscles but not changes affecting contractile proteins (25). Immobilization also reduces the affinity of muscle testosterone receptors (7 ,8).

Role of glucocorticoids

Numerous investigations (reviewed in ref. 7) have shown that hypercorticism is associated with a reduction in muscle mass. This muscular atrophy results from a negative nitrogen balance impairing protein synthesis and enhancing protein degradation. This response is selective of the type of muscle fiber : protein catabolism is clearly greater for fast twitch fibers , slow twitch fibers being more resistant to the atrophying effect of glucocorticoids. Physical training refrains this catabolic action of glucocorticoids on the skeletal muscle. This protective effect is much more efficient for type 1 slow twitch fibers.

Role of thyroid hormones

The skeletal muscle is a priority target for thyroid hormones whose main role is to regulate the synthesis of the various types of contractile proteins. The elevated concentrations of thyroid hormones increase the synthesis of fast contractile proteins and the formation of fast twitch fibers. Inversely, hypothyroidia reduces the number of fast twitch fibers (7).

Role of growth hormone (GH)

The Role of growth hormone (GH) on growth and protein synthesis of the skeletal muscle is well documented. The study of animals bearing pituitary tumors secreting GH shows an increase in the weight of muscles and in the surface of type I slow twitch fibers, the surface of type II fast twitch fibers being little influenced by GH. This enlargement of muscle volume is the result of an increase in protein synthesis. There is an increase in the number of satellite cells in young animals but not in adult animals. Such structural modifications in the skeletal muscle do not induce typological changes. GH can act either in direct interaction with a muscle receptor, or by increasing somatomedine concentrations in the muscle.

2. EFFECT OF TRAINING ON AGEING PROCESS

Effect of ageing and physical training on bone tissue

The decrease in bone density associated with age is a well known phenomenon. As other tissues, bone is a dynamic system which maintains its condition by constant renewal. Bone remodeling diminishes with age (15). It has been shown that physical exercise is capable of counteracting osteoporosis associated with ageing. It seems that this is a long term effect The

increase in bone capital at midlife resulting from intense physical activity could be the main factor of protection against ageing. The increase in bone density is mainly due to mechanical factors acting on the bone (16). However, the role of hormonal factors should also be mentioned. The metabolism of bone cells is influenced by the parathormone-calcitonine couple, but also by androgens, GH and thyroid hormones. Bone demineralization is observed during overtraining , due to hypogonadism which develops under such circumstances. We can therefore hypothetize that the hormonal response to physical training can affect bone.

Concerning support tissues, bone and muscle, it can be hypothetized that the increased concentrations in anabolizing hormones under the effect of well conducted physical training can explain muscle and bone anabolism.

Effect of physical training on the immune system

The effects of physical exercise on the immune system have recently been reviewed (3).

Isolated physical exercise increases practically all classes of leukocytes and lymphocytes. The appearance of leukocytes in blood probably results from the various shifts of immunocompetent cells among the various pools of the body. This mobilization of leukocyte classes is selective and does not exceed 24 hours. Chronic physical exercise seems to diminish the number of certain immunocompetent cells although this has not often been demonstrated. The meaning of changes in the numbers of cells induced by isolated physical exercise can be discussed. In the case of chronic exercise they could be interpreted as a sign of immune deficiency in the sportsman. They could also explain changes in the activities of immunocompetent cells.

The mechanisms of this immune deficiency observed in sportsmen remain to be unequivocally confirmed by clinical observation and the many immune changes associated with physical exercise are, so far, mostly unknown. However, two mechanisms could be involved : changes in number and activity of immunocompetent cells. Thus, changes in the activity of "natural killer" cells induced by exercise could be partly explained by changes in the numbers of these cells whereas other activities could be affected by hormonal changes. The increased concentrations of glucocorticoids and catecholamines and the depressed concentrations of circulating androgens could induce a hormonal syndrome causing immune deficiency in the endurance athlete.

3. HORMONAL RESPONSE TO TRAINING IN YOUNG AND AGED SUBJECT

Hormonal responses to physical exercise in young subjects

A synthesis of hormonal responses to physical exercise in young subjects has been derived from several reviews on this topic (4, 23).

Short intense physical exercise induces a very rapid increase in catecholamine concentrations resulting in a decrease in insulin and an increase in glucagon. This type of exercise also induces an increase in the levels of GH, testosterone and glucocorticoids. During prolonged exercise these hormonal changes tend to amplify, except for plasma testosterone which decreases :

- physical training modifies resting concentrations of several hormones
- insulinemia decreases in young trained subjects
- a high testosterone/cortisol ratio is observed in well trained subjects

Inversely, overtraining depresses testosterone concentrations and hypophyseal reactivity to such stimuli as hypoglycemia.

Several hypotheses can be derived from these observations :

1) the effects of physical exercise on pancreatic hormones (insulin-glucagon) and catecholamines could be the cause of the enhanced tolerance to glucose and lipid metabolism.

2) the effects of physical exercise on anabolizing hormones (GH, androgens) could enhance bone and muscle protein metabolism.

3) the effects of very long and exhausting exercises, such as depressed anabolizing hormones and prolonged increase in glucocorticoids, could result in bone demineralization and depressed immune defences.

We will verify whether such hormonal effects are also observed in aged subjects performing physical exercise.

3.2. Effect of physical training on the metabolic and hormonal response of middle-aged subjects

Insulin, glucagon, catecholamines and metabolism

The tolerance to glucose of endurance trained subjects (mean age 46) has been compared with that of young athletic and sedentary subjects (mean age 19) (6) . The middle-aged sportsmen ran 60 km a week and had a VO_2 max of 63 $ml.min^{-1}.kg^{-1}$. Glucose and insulin responses were identical in both populations of sportsmen (young and middle-aged) and substantially lower than in the two sedentary groups. Two investigations have been performed on older trained

subjects (60-70 years old) in order to compare their resting insulinemia with that of sedentary subjects of the same age or younger (10, 17). Improved sensitivity to insulin under the effect of training seems constant at all ages. This effect seems affected by a short period of inactivity so that one could conclude that regular exercise protect against the development of insulin resistance and normalize glucose tolerance in aged subject by means of a short term effect of exercise (20).

The response to prolonged sub-maximal exercise shows differences in the regulation of glycemia between trained and sedentary subjects. During a 60 minute exercise at 70% VO_2 max glycemia increased in aged and young physically trained subjects whereas it decreased in sedentary subjects of both age groups. This phenomenon can be due to a better ability of trained subjects to tap glycogen stores. The response to glucagon is much lower in both trained groups. A more substantial rise in catecholamines concentrations is observed in both trained groups, indicating that training enhances sympathetic stimulation.

A direct study using labelled noradrenalin perfusion confirmed the fact that physical training significantly increases the production of catecholamines in aged trained subjects but does not affect clearance (18). The authors correlate this increase in sympathetic stimulation with the increase in resting metabolism (Fig. 4).

In 40-70 year old subjects physical training thus significantly increases sensitivity to insulin and sympathetic tone. These two hormonal factors play a direct role in the improvement of lipid metabolism and reduction in fatty mass of aged trained subjects compared to their sedentary counterparts (22). The first hypothesis regarding the role of hormones on energetic metabolism is confirmed : in middle-aged subjects physical training increases the efficiency of insulin and circulating catecholamines on target tissues controlling the regulation of the energetic metabolism.

3.3. Hormones affecting bone and muscle condition

Androgens

The gradual decrease in androgen concentrations with the progression of age has been extensively described. During an investigation on responses to stress assays were made on middle-aged sportsmen competing in a modern pentathlon (8). The mean age of the group was 44. At the time of this investigation subjects were training one hour a day on the average ; three subjects had trained for three hours a day during the three weeks prior to the investigation. Resting plasma testosterone concentration in this population was 2.96 ± 0.28 mg.ml $^{-1}$. It was lower than that of younger athletes (mean age 23) participating in the same contest (4.88 mg.ml $^{-1}$) and that of 45 year old sedentary subjects (4.25 ± 0.18 mg.ml $^{-1}$).

Under the effect of the stress associated with a rifle shooting contest testosterone concentration respectively increased by 63% and 56% in populations of older and younger athletes. These results show that intense physical training at a sport with several events such as the modern pentathlon decreases the plasma testosterone concentration both in younger and older athletes. Concentrations measured in the younger athletes were lower than those measured in a population of athletes practising strength sports (4.88 ± 1.30 mg.ml $^{-1}$ vs 6.22 ± 0.12 mg.ml $^{-1}$). This data confirms Hackney's results (9) which showed a drop in plasma testosterone under the effect of intense endurance training. Older athletes react the same way as younger ones. The decrease takes place from a mean resting level lowered by age-related changes. The concurrence of these two factors reduces testosterone levels in older athletes to very low absolute values. The case by case examination shows the lowest values in the three older athletes who intensely prepared for this contest. Their performance was good : one ranked second for all tests, the other two ranked among the fist five winners . This underlines the fact that depressed testosterone levels resulting from intense physical training does not preclude good performance.

The resting levels and the response of glucocorticoids to stress is identical in both populations of athletes. If we consider as valid the fact that the ratio Testosterone/cortisol_reflects the anabolic condition, we could believe that older athletes are in a catabolic phase. In the absence of clinical signs reflecting muscular or bone intolerance other factors controlling muscular anabolism have to be identified. GH has been considered as playing a possible role. The data of Hagberg et al. (10) show that resting GH concentrations are the same in young and older athletes and in their sedentary counterparts. However, the increase in GH under the effect of physical exercise is lower in aged athletic and sedentary populations. The response of somatomedines to physical exercise is much higher in the younger athletes. These results seem to indicate that the anabolic stimulus resulting from the effect of physical exercise on GH secretion is lower in older subjects.

The tone of the two main hormonal pathways involved in muscle and bone anabolism seems therefore reduced in middle-aged athletes. The good muscle and bone adaptation of these subjects indicates that these pathways probably play a secondary role. Trophic factors resulting from mechanical constraints applying to bones and muscles and the role of innervation on muscles probably compensate for depressed hormonal secretions. A hypothesis could be suggested, correlating

the depressed thyroid secretions with the increasing number of slow twitch fibers under the effect of age but results are controversial.

Poehlman et al. (17) reported that neither physical training nor ageing modify the resting concentrations of thyroid hormones. Inversely, Hagberg et al. (10) showed that physical training reduces concentrations of thyroid hormones in young and older athletes. This could explain the increase in the number of slow twitch fibers under the effect of endurance training.

Data published on the response of anabolizing hormones in middle-aged subjects only concern endurance training. Results are not conclusive of an anabolizing effect of hormonal adaptations and partly discredit our second hypothesis. However, it would be indispensable to study the hormonal response of middle-aged subjects to strength training protocols.

The third hypothesis concerns the effect of a prolonged increase in the concentrations of glucocorticoids associated with a decrease in androgens on immune defences and bone density. Results obtained on middle-aged subjects confirm the decrease in androgens under the effect of intense physical training. Resting glucocorticoid levels do not seem to be modified. The reactivity of glucocorticoids to physical exercise or stress is normal. It may therefore be suggested that overtraining can induce a catabolic condition in middle-aged subjects as it does in younger ones. However, no result has so far evidenced a reduction in bone density or immune defences in intensively training aged subjects. The only point that we can discuss is indirect : the number of cancers in physically trained populations. Although cancer genesis involves a variety of factors, results suggest that the incidence of this disease tends to diminish in physically active populations. If physical exercise really depresses immune defences, it is possible that the total number of neoplasms tends to increase.

However, the relationship between the ratio testosterone/cortisol, the type of training and the immune system should be investigated.

In conclusion, the study of the hormonal response of middle-aged subjects to physical exercise indicates a very strong relationship between the increased sensitivity to insulin, the increase in sympathetic tone, and the improvement of the lipid balance and body composition.

Changes in the secretion of hormones acting on bone and muscle tissues, such as androgens, GH, and thyroid hormones are not sufficient to completely explain the beneficial effects of physical training on the bone/muscle system.

The negative effect of intense physical training on the immune system or bone density should be further studied, with reference to the hormonal response of middle-aged subjects to physical exercise.

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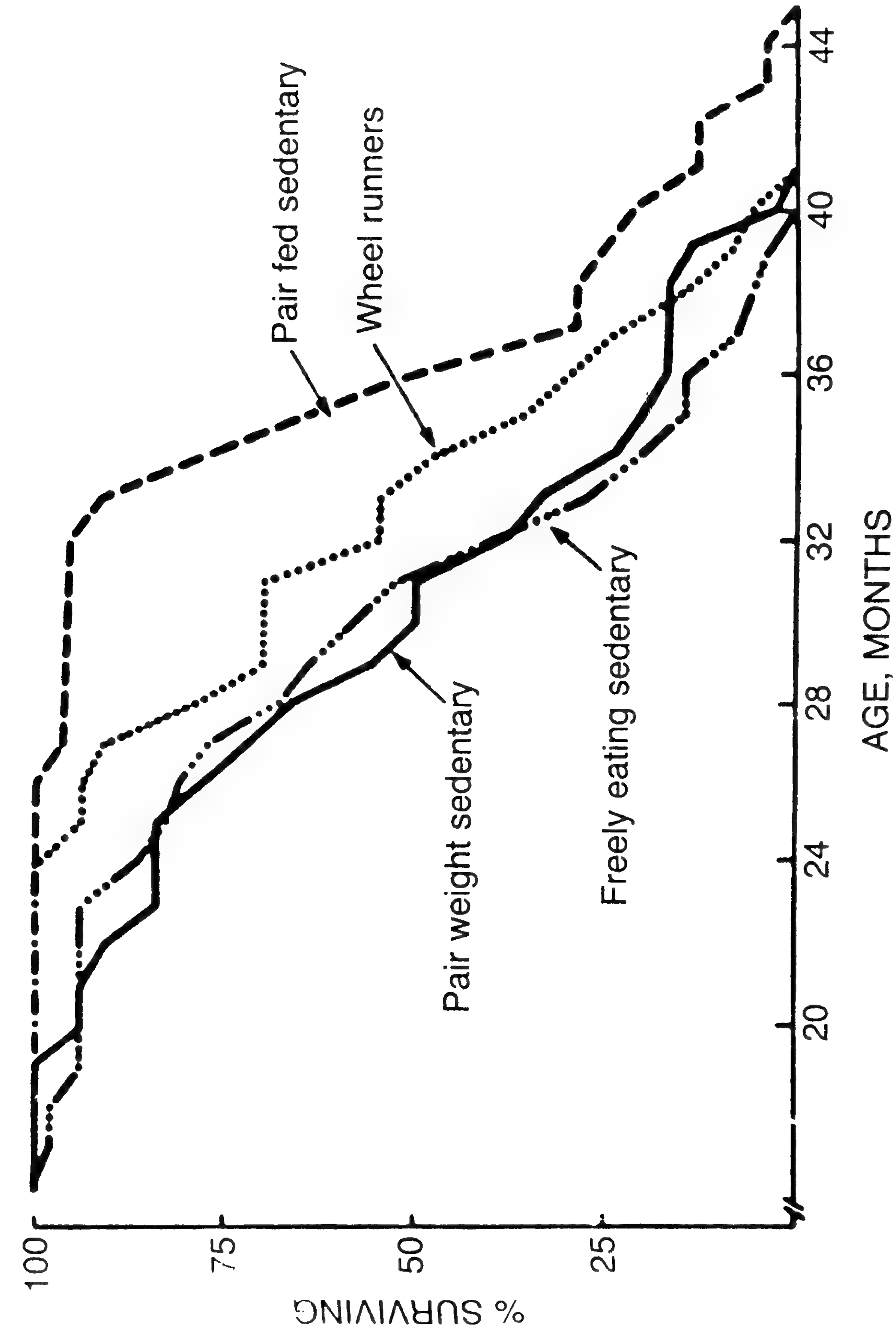
FIGURE 1 :
Survival curves for rats submitted to physical training (wheel runners) or food restricted (pair weight sedentary) compared to sedentary rats (from ref. 11)

FIGURE 2 :
Effects of 3 weeks of treadmill running training on 2 deoxy glucose transport in soleus muscle of rat (T: trained rats ; C: control sedentary rats)(from ref. 6)

FIGURE 3 :
Effect of physical training and food restriction on soleus muscle mass of youngs and 27 month aged rats (from ref. 2)

FIGURE 4 :
Norepinephrine metabolism before (pre) and after (post) endurance training at rest in aged subjects (from ref. 18)



% SURVIVING
100
75
50
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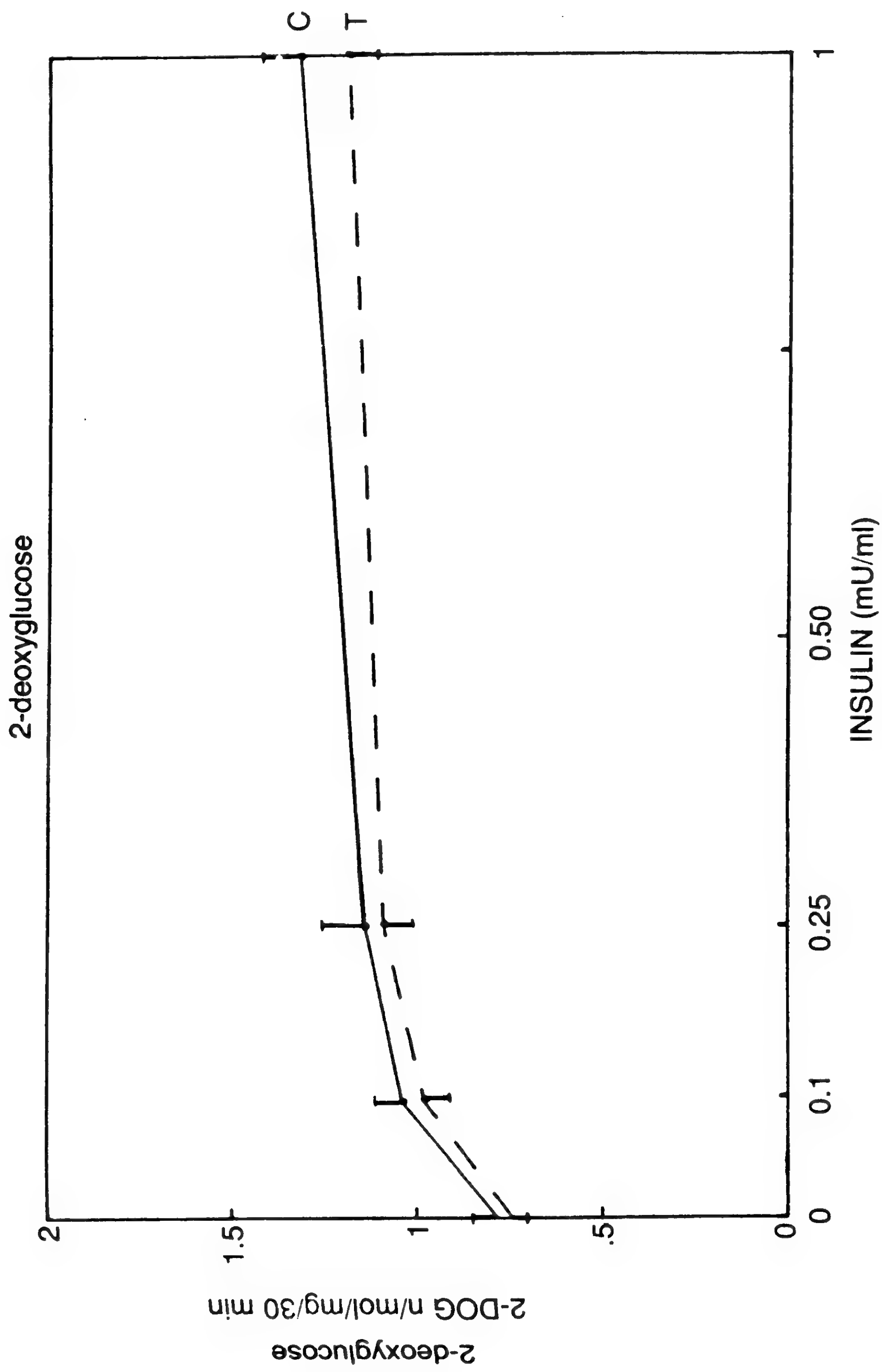
AGE, MONTHS
20
24
28
32
36
40
44
Pair fed sedentary
Wheel runners
Pair weight sedentary
Freely eating sedentary


2-deoxyglucose
2-deoxyglucose
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INSULIN (mU/ml)
0
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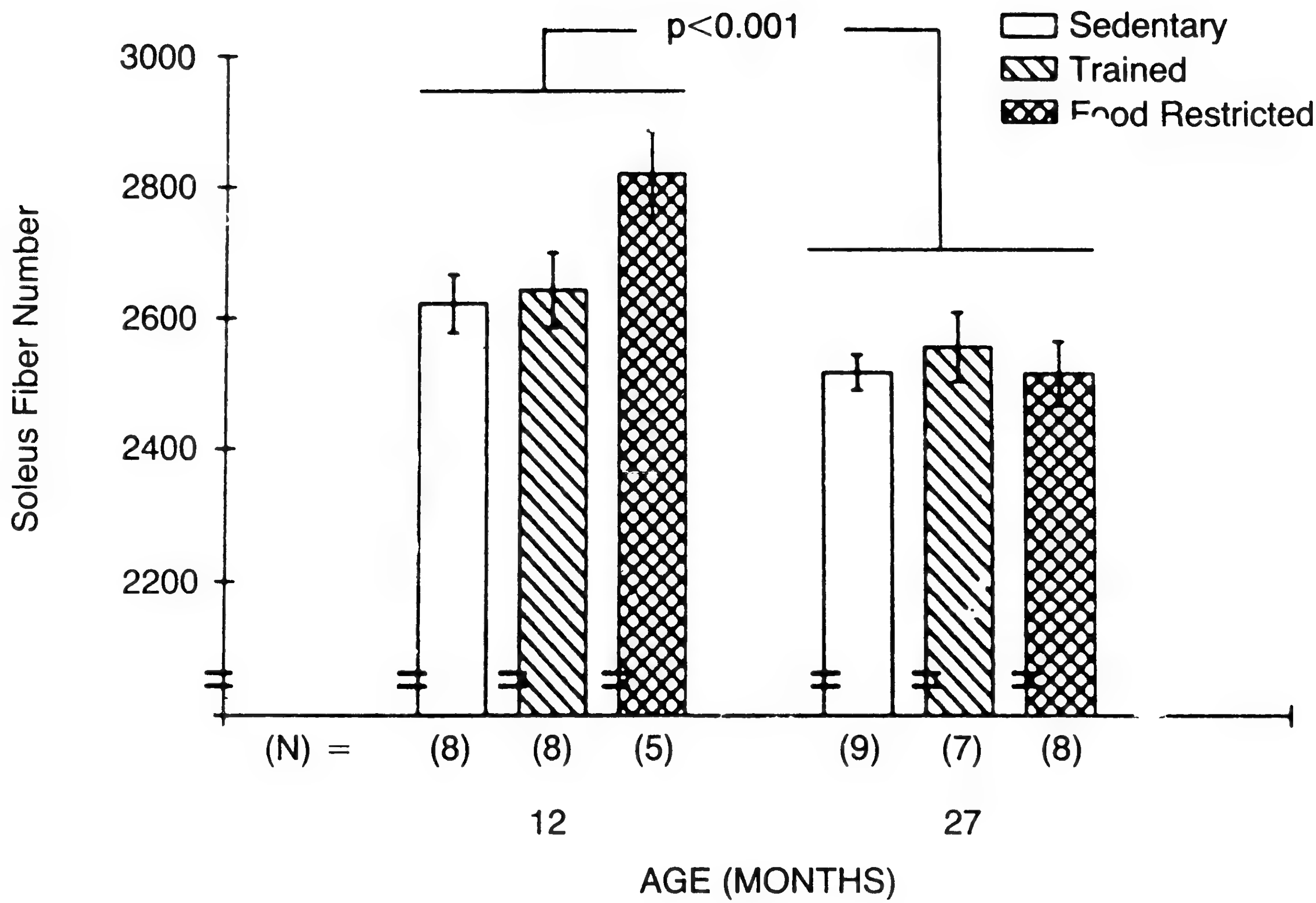
p<0.001
Sedentary
Trained
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3000
2800
2600
2400
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(N) =
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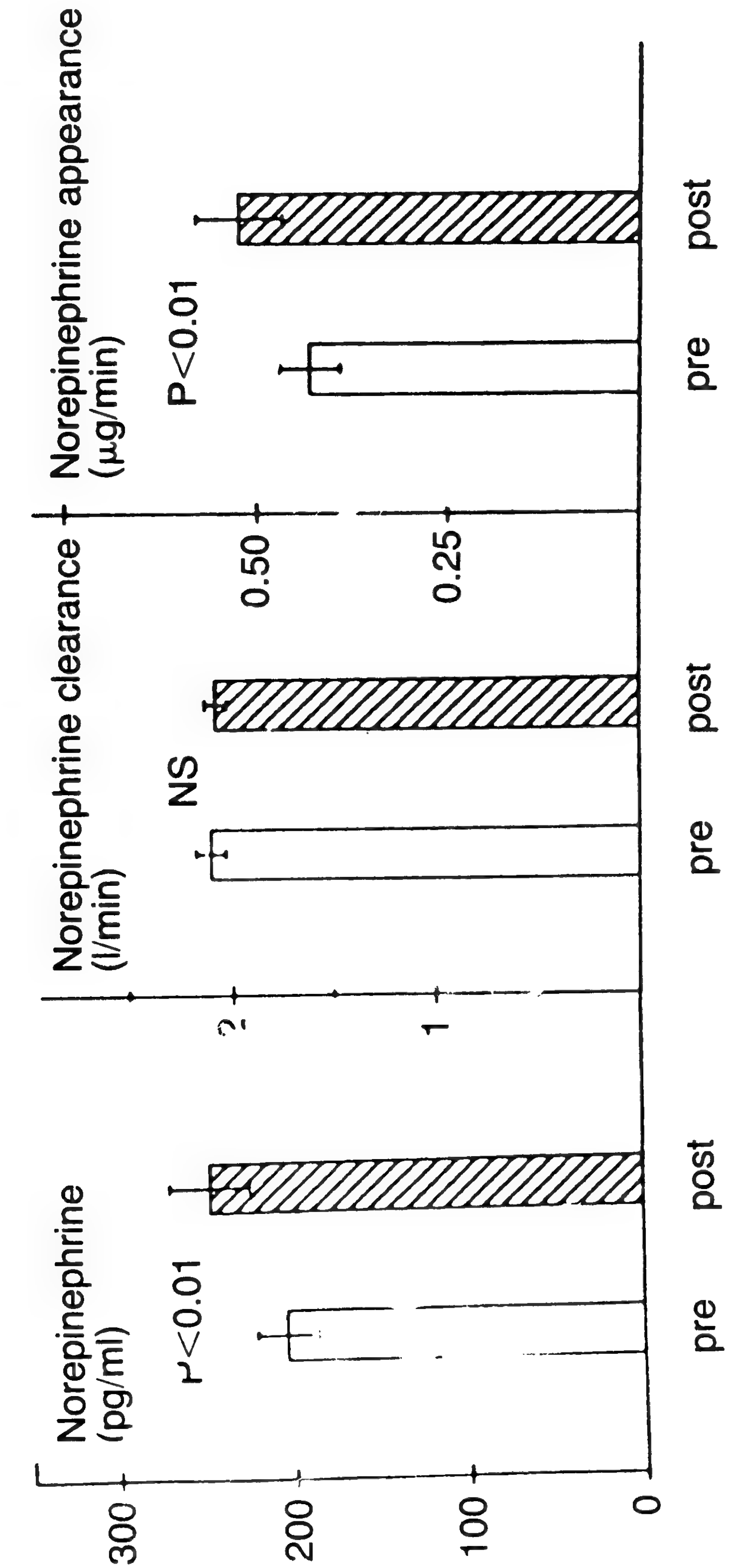
AGE (MONTHS)


Norepinephrine (pg/ml)
P<0.01
300
200
100
0
pre
post
Norepinephrine clearance (l/min)
NS
2
1
pre
post
Norepinephrine appearance (µg/min)
P<0.01
0.50
0.25
pre
post

AGE EFFECT ON AUTONOMIC CARDIOVASCULAR CONTROL IN PILOTS

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ABSTRACT

The autonomic cardiovascular control was determined as a function of age in 66 military pilots and in 39 referents, both groups aged from 20 to 55 yr. It was assessed by time-domain and frequency-domain heart rate variability (HRV) measures and with some HRV-derived indices. Most sensitive to aging process from time-domain HRV measures revealed to be short-term variability and time-domain index, and from frequency-domain HRV measures frequency-domain index. The activity of both ANS branches was found to decline with age, but a different extent of decrease of sympathetic as compared to parasympathetic activity was observed: sympathetic activity reflected by the spectral power of the R-R intervals in the temperature - mediated spectral frequency band (0.01-0.05 Hz) decline more slowly than parasympathetic activity reflected by respiratory sinus arrhythmia - mediated spectral frequency band (0.15-0.50 Hz). As well as such age-desynchronized autonomic cardiovascular control was found only in military pilots but not in referents it is concluded that the aging process in pilots is accelerated due to repetitive and prolonged exposure to persisting stress, caused by the compulsory underload (substantial reduction of flying tasks and physical exercises coinciding with personal interviews). Although the computed Overall Health Risk values in both groups were not substantially deviated from "normal", those in military pilots was significantly higher.

INTRODUCTION

Aging process is accompanied with regular changes in the repair and maintenance of most physiological functions. Functional response integrity and its adaptive capacity are affected by age. During aging process physiological functions perturb different extent of changes.
Age-associated neural, receptor and end-organ changes modify integration and regulation of cardiovascular responses. Mechanisms governing cardiovascular regulation, involve in part autonomic influences.

Considerable interest exists on the effects of age on the Autonomic Nervous System (ANS) that raises the question how to measure autonomic function quantitatively. Heart rate fluctuations are result of reciprocal control of the sympathetic and parasympathetic activities. As normal variations in resting heart rate are due to the tonic changing levels of activity of both ANS divisions, Heart Rate Variability (HRV) has been the focus of previous and recent studies on the effect of age on the ANS. HRV is a noninvasive method for assessment of autonomic nerve activity. Three components of HRV are involved in the autonomic control of heart rate fluctuations:

HRV Components

1. Temperature component of heart rate fluctuations in the frequency band: 0.01 - 0.05 Hz, related to thermoregulatory and peripheral vascular mechanisms, mediated by sympathetic activity (2; 26).

2. Traube-Hering-Mayer wave component of heart rate fluctuations in the frequency band: 0.06 - 0.14 Hz, reflected short-term blood pressure regulation, jointly mediated by sympathetic and parasympathetic activities (2; 35; 45).

Paper presented at the RTO HFM Symposium on "Operational Issues of Aging Crewmembers", held in Toulon, France, 11-14 October 1999, and published in RTO MP-33.

3. Respiratory Sinus Arrhythmia (RSA) component of heart rate fluctuations in the frequency band 0.15-0.50 Hz, reflected respiratory related fluctuations in heart rate variations, mediated by parasympathetic activity (2; 24; 45).

Aging process in military crew members could be magnified by repetitive and prolonged exposure to the stressful work environment or may be counterbalanced by the effect of training and expertise. Military pilots are exposed to different kinds of stressors in execution of their missions and stressors induced by work environment factors(1; 13; 17; 30; 31; 39; 46). Stress causes distracting and dysfunctional activation which prolongs after completing of the mission tasks (15). A number of studies have investigated the impact of the mission demands and simulated flight tasks on HRV components (17; 57; 60). However age effect on autonomic cardiovascular control in military pilots is not described in full.

Available studies in cardiovascular psychophysiology are devoted to the controversial problem of the age effect on autonomic cardiac control in healthy subjects.

AGE EFFECT ON SYMPATHETIC AND PARASYMPATHETIC ACTIVITIES ASSESSED BY HRV IN HEALTHY SUBJECTS

Studies based on HRV analysis have focused on two alternative conceptualizations of age effects on sympathetic and parasympathetic activity, that both branches decline with age or that the relative dominance of the two branches changes with age.

First Conceptualization

First conceptualization concerning the age effect on autonomic cardiovascular control elucidates that both sympathetic and parasympathetic activities decline with age. Aging is characterized by an impaired autonomic modulation which is reflected by reduction of the spectral powers of the HRV components: temperature-, T-H-M wave and RSA bands. The decreasing of spectral power of temperature component (which depends largely upon adrenergic activity) and spectral power of RSA component (which is a marker of parasympathetic function) with age are attributed to decline in efferent vagal cardiac tone and decreased adrenergic responsiveness associated with increased age (11; 14; 52; 53; 56). Except declining of the spectral powers in these HRV components in the Atherosclerosis Risk in Communities Study it was found that their spectral ratio also is inversely associated with age (age range: 45-64 yr) (32). These findings have been reported in other studies including examination of time-domain HRV measures and have been discussed as declining of parasympathetic and sympathetic influences mediating HRV components with increasing age (23; 33; 40; 56). The temperature component, the RSA component and the temperature-/RSA-band ratio (currently considered the spectral marker of sympathetic activity) diminish with age (age range: 25-85 yr) but distinction of previous results is a more pronounced age-related decline in sympathetic activity that begins about the sixth decade of life (34; 44). In young people a trend of predominating vagal tone was observed but in the elderly the respective decreases of sympathetic and parasympathetic components are of an almost similar importance (50). Age-associated decline in autonomic function has been confirmed by the inverse relation of RSA, T-H-M wave HRV components and peak O_2 consumption with age (7; 55); and by inverse relation of HRV spectral components, and baroreflex sensitivity with age (29).

Sensitivity of the quantitative assessment of the autonomic abnormalities in aging increases with studies involving postural manipulations. The spectral powers in temperature band (depending on adrenergic activity), the temperature-/ RSA-band ratio (marker of sympathetic activity) and the total spectral power of HRV diminish with age and appear depressed in the elderly subjects after postural tilt-testing (28; 51; 61). Reduction with advancing age of the T-H-M wave (0.10 Hz variability) and the RSA component after postural change indicate the depressed activity of sympathetic cardiac nerve activity, reduced cardiac vagal modulation and impaired baroreflex sensitivity at upright rest in older subjects (7; 42; 48). Contrary when uses gradual orthostatic load testing in the young adult (20-35 yr) and late middle-aged (50-66 yr) groups, the average values of the sympathovagal transition were almost equal (5).

Several cardiovascular reflex tests have been used to assess the dependence of autonomic function on age. Examination of the cardiac reflex tests (mean value of R-R intervals at normal and deep breathing; ratio of the R-R intervals at maximal tachycardia to R-R intervals at body tilt; orthostatic ratio of the R-R intervals at 30/13 s; heart rate reaction at Valsalva ratio) show significant negative correlation of HRV with increasing age (43). Cardiovascular responses to specified tests have been utilized as they are known to be mediated by autonomic control.

Second Conceptualization

Second conceptualization concerning the age effect on autonomic cardiovascular control elucidates that the relative dominance of the sympathetic and parasympathetic activities changes with age. Aging affects cardiac autonomic control as reduces the relative dominance of parasympathetic nervous system in controlling rhythmic variations of resting heart rate (18; 48; 49). The relative ratio of parasympathetic to sympathetic activity in supine rest is 6:1; for young and middle-aged groups the ratio is 9:1, resp. 3:2 (48; 49). The decreasing of HRV has been attributed to

diminished vagal activity accompanying aging (25; 36). Strong evidence for declining of parasympathetic activity is the change of RSA component of HRV. An inverse linear relationship between the RSA amplitude and age (21-54 yr) has been found (18) but no further decrease in RSA has been observed after age 50 yr in normal subjects (59). The inverse relationship of RSA and age has been confirmed, where RSA amplitude rapidly decreases from 20 to 35 yr and then shows no further decrease up to 78 yr (19). The RSA amplitude falls approximately 10 percent per decade (20). Pronounced reduction of respiratory related heart rate oscillations in the frequency range (0.15-0.40 Hz) compared with preserved vasomotor rhythms is found (38).

Contrary to these findings other studies suggest the theses of age-associated declining or increasing of relative dominance of sympathetic activity in autonomic cardiac control. Relatively larger decline has observed in the temperature- , and the T-H-M wave HRV components (related to thermoregulatory, vasomotor and renin-angiotensin control mechanisms) compared to respiratory component (22). In contrast to the observed decline in the temperature- and the T-H-M wave HRV components, an increasing of the temperature-/the RSA ratio (spectral marker of the sympathetic activity) and the spectral power in the temperature band (currently considered sympathetically mediated) in another studies are attributed to increase in relative dominance of the sympathetic influence in autonomic cardiac control with age (8; 61; 62).

In summary it can be stated that changes of the parasympathetic and sympathetic mediation of heart rate are important determinants of age dependence of HRV and are involved in the age genesis of the HRV components. Aging may cause opposite effects on the autonomic functioning: reduction of both sympathetic and parasympathetic tone; pronounced attenuation of the predominance of the parasympathetic activity and/or declining, resp. increasing of the relative dominance of the sympathetic activity. These data indicate that the problem of whether both sympathetic and parasympathetic tone is changed to the same extent with age is controversial.

Examination of the age-associated ANS functioning will contribute to the clarifying of the effect of aging on sympathetic and parasympathetic branches of the ANS in military pilots.

The aim of the present study was to determine the functional role of the autonomic cardiovascular control as a function of age in military pilots.

Determination of age-modified autonomic control in military pilots would help to understand whether stressful work environment would alter the pattern of normal aging process.

This study will test the hypothesis that the functional role of the autonomic cardiovascular control is changed as a function of age. The proposition inherent in this hypothesis is that a cause-effect relationship exists between age-modified autonomic control and cardiovascular function.

METHODS

Subjects

Two groups of subjects participated in this study: military pilots and referents (employees). First group consisted of 66 male military pilots employed by the Bulgarian Military Air Force and students of the Bulgarian Military Air Academy whose ages ranged from 20 to 55 years (mean age X±SD 34.85±10.71). Referent group consisted of 39 male subjects who were employees in institutions matched for age (X±SD 34.13±11.00; age range: 20 to 55 yr) to the military pilots.

Criteria for exclusion included: systolic blood pressure>130 mmHg; diastolic blood pressure>85 mmHg; body-mass index>25 kg/m$^{2;}$ smoking; using medications; diabetes; cholesterolaemia; and a history or evidence of cardiovascular, respiratory, renal, hepatic, gastrointestinal or systemic disease.

Procedure

HRV data were determined from 10 min ECG recordings between 9 a.m. and 11 a.m. in supine position after 1 h rest period. HRV data were obtained in three consecutive days and mean individual values from the measurements were calculated.

Heart Rate Variability

Computerized method for analyzing of HRV was applied (12). An ECG was registered from a bipolar standard Ist lead.

A portable electronic device was used to transform ECG signal into R-R intervals and to emit (transmit) R-R intervals to IBM compatible PC for on-line processing. ECG signal is transformed to R-R intervals by AC converter (QRS detector and timer, resolution time 2224 samples per second). This sampling rate gives a variation of 0.48 msec in locating the peak of R-wave and results in a minimum accuracy of 99.55 % in computing heart rate up to 140 beats/min.

Time-domain and frequency-domain HRV measures, and HRV derived indices were analyzed:

1. Time-domain HRV measures:

X (mean R-R interval) (msec), resp. mean heart rate (beats/min); Short-Term Variability (STV) (msec) (reflecting respiratory oscillations in heart rate variations); Long-Term Variability (LTV) (msec) (reflecting baroreceptory- and thermoregulatory influences on heart rate variations); Time-Domain Index (TDI) (arb. un.) (assessing sympathetic/parasympathetic influences on histogram R-R intervals distribution).

2. Frequency-domain HRV measures:

Spectral power of the R-R intervals in the Temperature band (0.01-0.05 Hz) (P_T) (ms^2) (sympathetically mediated); spectral power of the R-R intervals in the Traube-Hering-Mayer band (0.06-0.14 Hz) (P_{THM}) (ms^2) (sympathetically and parasympathetically mediated); spectral power of the R-R intervals in the Respiratory Sinus Arrhythmia (RSA) band (0.15-0.50 Hz) (P_{RSA}) (ms^2) (parasympathetically mediated); Frequency-Domain Index (FDI) (P_T/P_{RSA}) (arb. un.) (reflecting sympathetic/parasympathetic activity ratio). Spectral powers of the R-R intervals in the respective frequency bands were calculated using Fast Fourier Transform.

3. HRV-derived indices:

Physical Stress (PS) (arb. un.) (mathematical algorithm based on difference between measured and age-referent values derived from the time-domain HRV measures); Mental Stress (MS) (arb. un.) (mathematical algorithm based on difference between measured and age-referent values derived from the frequency-domain HRV measures); Functional Age (FA) (yr) (mathematical algorithm computing difference between measured and age-referent values of autonomic activity derived from the frequency-domain HRV measures); Health Risk (%) (mathematical algorithm derived from PS-, MS-coefficients and number of premature heart beats).

Analysis of Data

HRV measures, HRV-derived indices and heart rate in referent and in military pilots groups are expressed as means ± standard deviations. Means of HRV variables were compared by independent samples t-test. To define correlations between age and HRV variables bivariate correlation analysis was applied (in referent group Pearson's correlation analysis; in military pilots group Spearman's correlation analysis). In referent group correlation analysis of Pearson was used as all variables including age were normally distributed. In military pilots group correlation analysis of Spearman was used as age was not normally distributed variable. Linear regression analysis was performed using age as independent variable and the measures of HRV as dependent variables. Logistic regression analysis (method forward: LR) was used to define which measures discriminate two groups of subjects. A p value lesser 0.05 was considered statistically significant.

RESULTS

I. Stress Differences

To examine whether military pilots and employees are exposed to stress influence in their jobs HRV measures were compared between both groups by independent samples t-test. HRV is a sensitive method for determination of disturbed autonomic function induced by stress factors of work environment (1; 12; 37). Mean values of HRV variables in both groups are presented in Table 1.

Table 1. Mean groups (X ± SD) and p-values of time- and frequency-domain HRV measures, HRV-derived indices, heart rate and age.

Variables	Referent group X ± SD	Military pilot group X ± SD	P-value
Age	34.13 ± 11.00	34.85 ± 10.81	n.s.
Heart rate (b/min)	72.3 ± 10.36	76.6 ± 10.71	0.04
STV (msec)	48.90 ± 16.38	52.77 ± 22.27	n.s.
LTV (msec)	37.92 ± 13.07	40.82 ± 14.53	n.s.
TDI (arb.un.)	69.21 ± 27.24	46.06 ± 17.83	<0.0001
X (msec)	846.18 ± 121.87	798.33 ± 112.83	0.04
$P_{(T)}$ (ms^2)	7.16 ± 2.83	9.29 ± 3.80	0.003
$P_{(THM)}$ (ms^2)	10.55 ± 3.82	11.79 ± 6.68	n.s.
$P_{(RSA)}$ (ms^2)	12.0 ± 5.55	8.76 ± 5.05	0.003
FDI (arb.un.)	38.86 ± 13.38	33.92 ± 14.54	n.s.
PS (arb.un.)	-0.76 ± 0.11	0.48 ± 0.08	<0.0001
MS (arb.un.)	0.43 ± 0.16	1.12 ± 0.24	0.01
HR (%)	25.82 ± 10.59	41.26 ± 22.08	<0.0001
FA (yr)	33.13 ± 8.79	36.70 ± 11.38	n.s.

Stress caused significant decrease of mean values of P_{RSA} , TDI and mean R-R interval in pilots compared to referents. Stress resulted also in significant increase of mean values of P_T, PS, MS, HR and heart rate in pilots. Fig. 1, fig. 2 and fig. 3 illustrate differences in mean values of P_T and $P_{RSA;}$ MS and resp. HR in both groups.

Fig. 1. Mean values of the $P_T(ms^2)$ and $P_{RSA}(ms^2)$ in referent and military pilots groups.

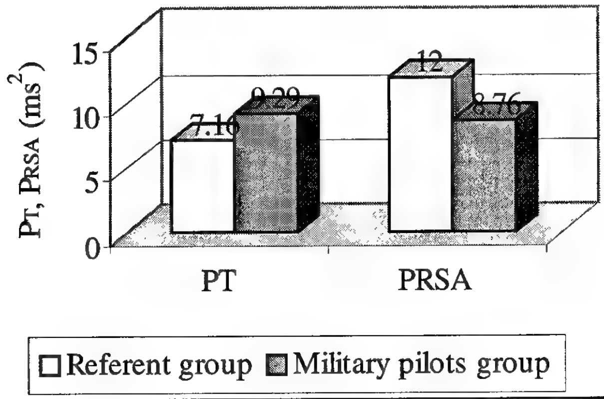


Fig. 2. Mean values of the MS (arb.un.) in referent (I) and military pilots (II) groups.

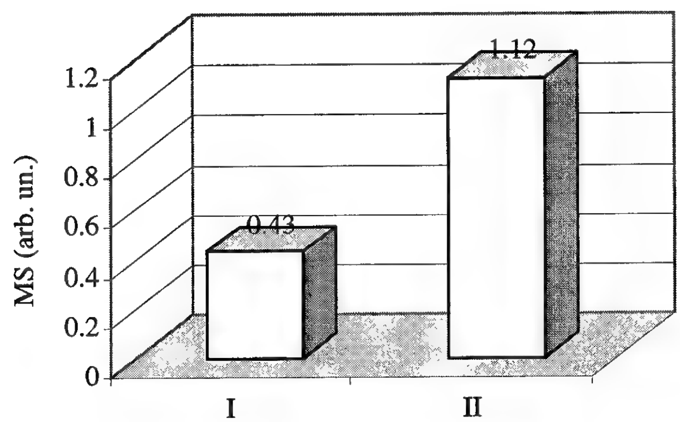
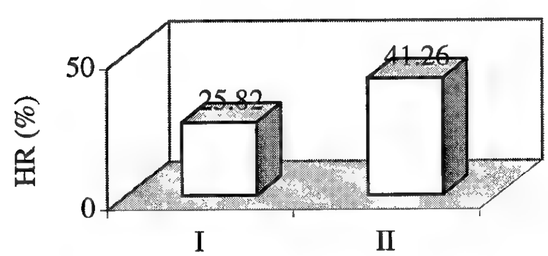


Fig. 3. Mean values of the HR (%) in referent (I) and military pilots (II) groups.



Logistic regression analysis (method forward: LR) (3) contributed for discrimination of pilots exposed to stressful demands of work environment from referents who were not exposed to stress impact. Four variables: STV, TDI, mean R-R interval and P_{RSA} thought sympathetically and parasympathetically mediated discriminate pilots of referents in this study (fig. 4). Probability one investigated subject to refer to referent group is assessed by first equation in fig. 4. Then, the probability of investigated subject to be a pilot is assessed by a second equation in fig. 4. The general discrimination power was 98.10 %, all pilots were correctly classified with exception of two referents.

Fig. 4. Equations of the logistic regression analysis (method forward: LR).

$$P(CC=0)=\frac{1}{1+e^{-(26.54+1.35STV-1.688TDI-0.026X+0.954P_{RSA})}}$$

$$\mathrm{P(CC=1)=1-P(CC=0)}$$

0 - referent group
1 - military pilots group

These results may indicate that:

- Military pilots are exposed to stress factors of work environment. Stress affects autonomic cardiovascular control in pilots.
- STV, TDI, X (mean R-R interval) and P_{RSA} are recommendable to be used for psychophysiological selection of pilots.

II. Age Effect on Autonomic Cardiovascular Control.

The effect of age on autonomic cardiovascular control was determined by correlation and linear regression analyses.

1. Correlations of Age with HRV

In military pilots were observed:

- Significant negative correlation of age with time-domain HRV measures: STV ($r=-0.55$, $p<0.0001$); LTV ($r=-0.53$, $p<0.0001$) and TDI ($r=-0.59$, p,0.0001).

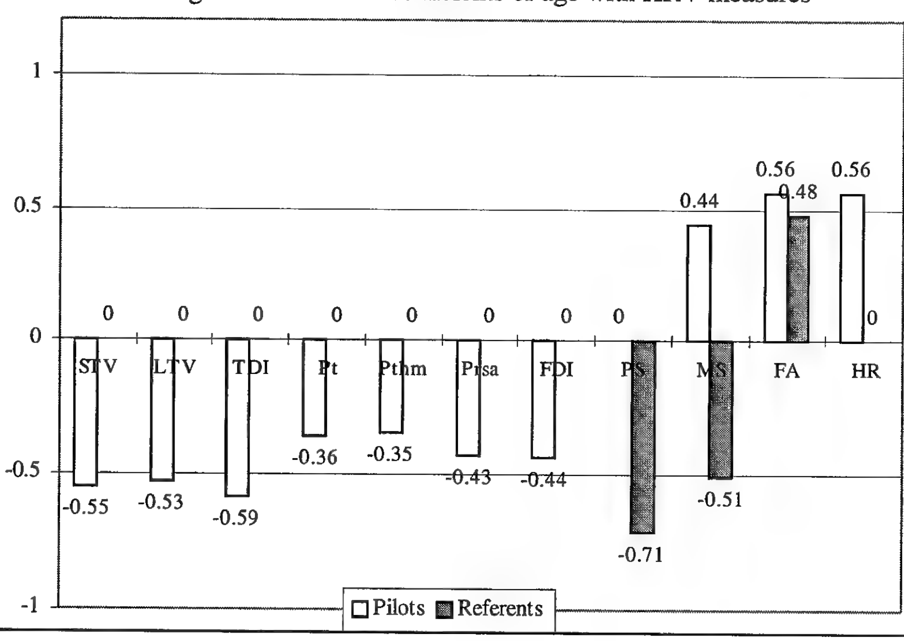
Mean R-R interval (X), resp. heart rate was unrelated to age.

- Significant negative correlation of age with frequency-domain HRV measures: P_T ($r=-0.36$, $p<0.001$); P_{THM} ($r=-0.35$, $p<0.001$); P_{RSA} ($r=-0.43$, $p<0.0001$) and FDI ($r=-0.44$, $p<0.0001$).
- Significant positive correlation of age with HRV-derived indices: MS ($r=0.44$, $p<0.0001$); FA ($r=0.56$, $p<0.0001$) and HR ($r=0.56$, $p<0.0001$).

In referent group significant correlations were observed between age and PS ($r=-0.71$, $p<0.0001$); MS ($r=-0.51$, $p<0.001$) and FA ($r=0.48$, $P<0.0001$).

Correlation coefficients of age with HRV variables in military pilots and referents are presented in fig. 5.

Fig. 5. Correlation coefficients of age with HRV measures



2. Age Dependencies of HRV

Autonomic cardiovascular control assessed by HRV declines progressively as a function of age in pilots. This pattern was observed for both time- and frequency-domain HRV measures.

- Time-domain HRV measures: STV and TDI decreased markedly with age while (whereas) LTV decreased more gradually with age. Regression coefficients are presented in table 2.
- Frequency-domain HRV measures: Differentiated spectral powers of R-R intervals in the respective frequency bands declined slowly with advancing age compared with time-domain HRV measures. Slowest extent of age decline showed P_T. Contrary to the slow decline of P_T, P_{THM} and P_{RSA}, FDI (P_T/P_{RSA}) demonstrated rapid decline with aging. Regression coefficients are presented in table 2.
- HRV-derived indices: In contrast to HRV measures MS, HR and FA increased progressively with advanced age. Regression coefficients are presented in table 2.

Table 2. Significant regression coefficients of dependence of age on HRV.

Variables		Referent group	Military pilot group
Time-domain HRV measures			
	STV	-	-1.00***
	LTV	-	-0.72***
	TDI	-	-0.97***
Frequency-domain HRV measures			
	FDI	-	-0.62***
	P_T	-	-0.09***
	P_{THM}	-	-0.20***
	P_{RSA}	-	-0.21***
HRV-derived indices			
	PS	-0.04***	0.04***
	MS	-0.03***	1.01***
	HR	-	1.15***
	FA	0.77***	1.01***
X (mean R-R)		-	-
Heart rate		-	-

***p<0.0005

In referents significant regression coefficients of dependence of age on HRV were observed for FA, PS and MS. Regression coefficients are presented in table 2.

3. Association of Health Risk with HRV measures

Although the Health Risk (HR) values were normal among both groups, HR was significantly increased in military pilots compared with referents (table 1 and fig. 3).

Age-modified autonomic cardiovascular control in military pilots was related to health risk. Correlation of age with HR is r=0.56, p<0.0001. Significant correlations were observed between HR and time-domain HRV measures: STV (r=-0.83, p<0.0001), LTV (r=0.71, p<0.0001), TDI (r=0.86, p<0.0001); and frequency-domain HRV measures: FDI (r=0.83, p<0.0001), P_T (r=0.45, p<0.0001), P_{THM} (r=0.72, p<0.0001), P_{RSA} (r=-0.86, p<0.0001).

In referent group significant correlations of HR with HRV measures were not observed.

DISCUSSION

Autonomic cardiovascular control examined by HRV measures and HRV-derived indices changed as a function of age in military pilots. Both sympathetic and parasympathetic mediated HRV measures: time-domain measures (STV, LTV and TDI) and frequency-domain measures (P_T, P_{THM}, P_{RSA} and FDI) declined with advancing age. The most sensitive changes to aging process revealed STV (thought to reflect respiratory sinus arrhythmia) (12; 47), TDI (thought to reflect sympathetic/parasympathetic influences on histogram R-R intervals distribution) (12) and FDI (thought to represent ratio of sympathetic/parasympathetic modulation on R-R intervals) (12).

Our results revealed that both ANS divisions declined with age but we observed different extent of decreasing of sympathetic and parasympathetic determinants involved in the age genesis of HRV components. It is important to note that the observed by us dependencies of age on HRV measures (assessed by linear regression analysis) are valid only for age range 20-55 yr.

Sympathetic activity mediating P_T declined more slowly with increasing age than parasympathetic activity mediating P_{RSA}. This pattern was observed also for age-associated LTV change. Compared to STV and TDI, LTV decreased more slowly with advancing age. In contrast to parasympathetically mediated RSA explaining STV change, LTV represents baroreflex- and thermoregulatory-related HRV that are sympathetically and parasympathetically mediated. This result is consistent with finding of Korkushko et al. (27) who reported a different pattern of impairment of sympathetic and parasympathetic tone: power in high-frequency band (0.2-0.4 Hz) declines from the

middle of the third decade of life whereas power in low-frequency band (0.01-0.05 Hz) declines linearly after age 50 yr.

More likely mechanisms for observed of us age-associated decline of both ANS divisions are decreased baroreceptor sensitivity, baroreceptor modulation of heart rhythm and blunted beta-adrenergic influences on the myocardium and vasculature. Age-associated desynchronized autonomic cardiovascular functioning might be accelerated by repetitive and prolonged exposure to persisting stress induced by underload effect on Bulgarian military pilots. The underload is related to substantially reduced flying tasks. The role of compulsory flying reduction as a strong stressogenic factor was supported by the results of personal interviews which revealed also a remarkable decrease in the physical exercises. Similar mechanisms explaining age-related changes in cardiovascular control in response to stressors were reported (21; 67). To further elucidate the effect of age on autonomic cardiovascular control under stress it would be important to extend our study with simultaneous analysis of factors underlying heart rate change as: cardiac output, total peripheral resistance, baroreflex sensitivity.

Our study did not reveal significant correlation or dependence of age with/on mean R-R interval, resp. mean heart rate. The most likely reason might be not strong enough level of stress. Correlation of age with heart rate might be observed in conditions of high overload (overstress) or acute stress. The other reason might be relatively modest heart rate change yielded by age-associated co-inhibited sympathetic and parasympathetic activities. Our study revealed significant dependence of age on PS. PS in military pilots increased with age as they possessed higher level of physical training than referents. The opposite dependence was observed in referents due to low level of training.

Vagal and sympathetic nerve activities are coordinated to achieve balanced operation of the cardiac rhythm. However the function of the ANS is not only a fixed reciprocal reaction but changes according to the stimuli or situations (4).

Our main finding concerning the functional response of age-desynchronized autonomic cardiovascular control in military pilots might be affected on:

- Pattern of acceleration of aging process in military pilots. The most likely mechanism for aging acceleration in military pilots is repetitive and prolonged exposure to persisting stress induced by underload. The underload is due to the substantial reduction of flying tasks. Flying tasks are reduced according to the specific economic situation in our country. Repetitive and prolonged exposure to underload stress condition accelerates aging process. In referents such pattern was not observed. In referent group correlation or dependence of age with/on HRV measures was not observed. Age did not exert significant influence on autonomic cardiovascular control in referents in age range: 20 to 55 yr as they were not exposed to stress factors in their work activity.
- According to the doctrine of the autonomic space of Cacioppo et all. (8) and Berntson et all. (4) our finding referring to age-modified autonomic cardiovascular control can be defined as "coupled non-reciprocal (co-inhibition) mode of autonomic control" due to decline of both ANS branches as a function of age. Grossman et all. (16) indicate that stress affects sympathetic and parasympathetic cardiac function. Under stress effects sympathetic and parasympathetic activities can vary independently, not only reciprocally (4; 8). Our results in this respect indicated age-related co-inhibition (concurrent decreases) of both sympathetic and parasympathetic activity under stress.
- Although the Health Risk values among both groups were normal, military pilots revealed higher values of health risk compared with referents. This might be due to the slowly decline of sympathetic activity with age rather than parasympathetic activity. Parasympathetic activity decline rapidly with advancing age. Reduced HRV is associated with increased cardiovascular risk (54). Probability for development of hypertension and coronary artery disease (CAD) is increased when health risk is increased above 65 % (12). In military pilots increased incidence of CAD, arrhythmia's and hypertension was observed above 35 yr (9; 10; 13; 41; 46). However in our study exact and precise assessment of health cardiac risk in military pilots could be done only if additional clinical and paraclinical measures would be examined.

In conclusion our results in military pilots demonstrated:

1. Autonomic cardiovascular control assessed by HV measures changed as a function of age.
2. Both ANS branches declined with age but we observed different extent of decrease of sympathetic and parasympathetic activity. Sympathetic cardiac activity declined slowly with advancing age rather than parasympathetic activity.
3. Pattern of acceleration of aging process. The most likely mechanism for aging acceleration is repetitive and prolonged exposure to persisting stress induced by underload due to substantial reduction of flying tasks.

4. According to the doctrine of the autonomic space of Cacioppo et all. (8) and Berntson et all. (4) the examined age-associated autonomic cardiovascular control can be defined as “coupled non-reciprocal (co-inhibition) mode of autonomic control”.

5. Although the health risk values among both groups were normal, military pilots revealed higher values of health risk compared with referents.

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"THE ASSOCIATION BETWEEN AGING AND BIOCHEMICAL-METABOLICAL INDEXES IN A RANDOM PERSONNEL SAMPLE OF HELLENIC AIR FORCE"

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INTRODUCTION-PURPOSE

The prolonged military operational stresses and the increased life expectancy may induce the appearance of several metabolic and cardiovascular disorders. The early diagnosis of these disorders could contribute to their prevention and effective management.

This study is a part of a long- term prospective investigation of association between aging and biochemical-metabolical indexes.

MATERIALS-METHODS

There was a random selection of 539 adults (519 men and 20 women). All of those were non-flying personnel of Hellenic Air Force, aging from 21 to 55 years old which were divided in 5-years groups and also in smokers and non-smokers groups.

The medical examination included a complete medical history and a full physical examination; blood pressure, anthropometric measurements and information about smoking, eating, physical activity, alcohol consumption were taken. Blood pressure was measured in a sitting position with a standard mercury sphygmomanometer with an 8X14 cm cuff. A 12-lead resting electrocardiogram (ECG) was performed.

A 15 cc blood sample was taken after 12-14 hours of fasting for the determination of the following parameters: lipidemic profile (total cholesterol, HDL, LDL, triglycerides, atheromatic index, apoA, apoB, Lp(a)), urea, creatinine, blood glucose, CRP, transaminases (SGOT, SGPT), fibrinogen, total bilirubin, potassium, sodium. For serum total cholesterol and HDL, the enzymatic colorimetric method was used. Also, BMI, systolic and diastolic arterial blood pressure, exercise levels, smoking and alcohol consumption were estimated.

All of the Hellenic Air Force non-flight personnel must pass every 2 years a complete medical examination (as described above) as well as in areas of neurology, ENT, dental, ophthalmology and psychiatry.

Descriptive statistics were used to compile data. Linear regression analysis were used to examine the association of the following variables: age, smoking, exercise, alcohol consumption, BMI, lipidemic profile (total cholesterol, HDL, LDL, triglycerides, atheromatic index, apoA, apoB, Lp(a)), urea, creatinine, blood glucose, CRP, transaminases (SGOT, SGPT), fibrinogen, total bilirubin, potassium, sodium. For the analysis of the results, SPSS 8.0 was used

RESULTS

Age: The mean age of 539 adults was 33.55 years, standard deviation 7.55 and the 10^{th}, 75^{th}, 90^{th} percentiles, were 24, 38, 44, respectively.

Smoking: We didn't find any statistical significant correlation between smoking and age **(TABLE 1a,b)**

Exercise: A ***negative poor statistical significant association*** between exercise and age, exercise and smokers, exercise and non-smokers was found.
(TABLE 2a,b)

Alcohol: A ***positive poor statistical significant association*** between alcohol and age, alcohol and smokers, was found. We didn't find any statistical significant correlation between alcohol and non-smokers **(TABLE 3a,b)**

BMI: The mean value was 25.942(±3.403) kg/m^2 and the 10^{th}, 75^{th} and 90^{th} percentiles were 22.526, 27.77, 29.83 kg/m^2 respectively. A ***positive poor statistical significant association*** between BMI and age, BMI and smokers, BMI and non-smokers was found.
(TABLE 4a,b)

Total cholesterol/HDL: The mean value was 5.42 (± 1,52) and the 10^{th}, 75^{th} and 90^{th} percentiles were 3.7, 6.23, 7.42 respectively. A ***positive poor statistical significant association*** between total cholesterol/HDL and age, total cholesterol/HDL and non-smokers and a

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less positive statistical significant association between total cholesterol/HDL and smokers, was found. **(TABLE 5a,b)**

Total cholesterol: The mean value was 217.4 (± 50,48)mg% and the 10th, 75th and 90th percentiles were 155.9, 251, 283.2mg% respectively. A ***less positive statistical significant association*** between total cholesterol and age, total cholesterol and smokers total cholesterol and non-smokers, was found. **(TABLE 6a,b)**

Triglycerides: The mean value was 121(± 101.68) mg% and the 10th, 75th and 90th percentiles were 35, 154, 228 mg% respectively. A ***positive poor statistical significant association*** between triglycerides and age, triglycerides and smokers, triglycerides and non-smokers was found. **(TABLE 7a,b)**

HDL: The mean value was 41.17(± 7.69) mg% and the 10th, 75th and 90th percentiles were 32, 45, 51 mg% respectively. A ***positive that trends to significance association*** between HDL and age, HDL and non-smokers was found. We didn't find any statistical significant correlation between HDL and smokers. **(TABLE 8a,b)**

LDL: The mean value was 151.94(± 45.51) mg% and the 10th, 75th and 90th percentiles were 93.98, 178.9, 231.55mg% respectively. A ***less positive statistical significant association*** between LDL and age, LDL and smokers LDL and non-smokers, was found.
(TABLE 9a,b)

apoA: The mean value was 1.38(± 0.22) g/l and the 10th, 75th and 90th percentiles were 1.11, 1.51, 1.66 g/l respectively. A ***positive poor statistical significant association*** between apoA and age, apoA and smokers and a ***positive who trends to significance association*** between apoA and non-smokers was found.
(TABLE 10a,b)

apoB: The mean value was 1.12(± 0.30) g/l and the 10th, 75th and 90th percentiles were 0.74, 1.32, 1.52 g/l respectively. A ***less positive statistical significant association*** between apoB and age, apoB and smokers, apoB and non-smokers, was found. **(TABLE 11a,b)**

Lp(a): The mean value was 13.74(± 17.95) mg/dl and the 10th, 75th and 90th percentiles were 2.5, 15.48, 36.63 respectively. We didn't find any statistical significant correlation between Lp(a) and age, Lp(a) and smokers, Lp(a) and non-smokers. **(TABLE 12a,b)**

Fibrinogen: The mean value was 258.87(± 60.95) mg/dl and the 10th, 75th and 90th percentiles were 206, 282.25, 327.1 mg/dl respectively. A ***positive poor statistical significant association*** between fibrinogen and age, fibrinogen and smokers was found. We didn't find any statistical significant correlation between fibrinogen and non-smokers. **(TABLE 13a,b)**

SGOT: The mean value was 26.81(± 7.39) units/l and the 10th, 75th and 90th percentiles were 20, 29, 34.1 units/l respectively. We didn't find any statistical significant correlation between SGOT and age, SGOT and smokers, SGOT and non-smokers. **(TABLE 14a,b)**

SGPT: The mean value was 32.71(± 17.71) units/l and the 10th, 75th and 90th percentiles were 17.9, 39.25, 53 units/l respectively. We didn't find any statistical significant correlation between SGPT and age, SGPT and smokers, SGPT and non-smokers. **(TABLE 15a,b)**

Total Bilirubin: The mean value was 0.69(± 0.386) mg/dl and the 10th, 75th and 90th percentiles were 0.3, 0.9, 1.2 mg/dl respectively. We didn't find any statistical significant correlation between bilirubin and age, bilirubin and smokers, bilirubin and non-smokers. **(TABLE 16a,b)**

Sodium: The mean value was 143.85(± 2.23) mEq/l and the 10th, 75th and 90th percentiles were 141, 145, 147 mEq/l respectively. We didn't find any statistical significant correlation between sodium and age, sodium and smokers, sodium and non-smokers. **(TABLE 17a,b)**

Potassium: The mean value was 4.395(±0.351) mEq/l and the 10th, 75th and 90th percentiles were 4, 4.6, 4.9 mEq/l respectively. A ***positive poor statistical significant association*** between potassium and smokers was found. We didn't find any statistical significant correlation between potassium and age, potassium and non-smokers. **(TABLE 18a,b)**

Urea: The mean value was 32.44(± 7.69) mg/dl and the 10th, 75th and 90th percentiles were 23, 37, 43 mg/dl respectively. A ***positive strong ,which trends to significance, association*** between urea and smokers was found. We didn't find any statistical significant correlation between urea and age, urea and non-smokers. **(TABLE 19a,b)**

Creatinine: The mean value was 0.937(± 0.155) mg/dl and the 10th, 75th and 90th percentiles were 0.8, 1, 1.1 mg/dl respectively. We didn't find any statistical significant correlation between creatinine and age, creatinine and smokers, creatinine and non-smokers. **(TABLE 20a,b)**

Glucose: The mean value was 87.61(± 10.11) mg/dl and the 10th, 75th and 90th percentiles were 76, 93, 101 mg/dl respectively. A ***positive poor statistical significant association*** between glucose and age, glucose and smokers, glucose and non-smokers was found.
(TABLE 21a,b)

CRP: The mean value was 3.948(± 2.236) mg/l and the 10th, 75th and 90th percentiles were 3.2, 3.4, 5.4 mg/l respectively. We didn't find any statistical significant correlation between CRP and age, CRP and smokers, CRP and non-smokers. **(TABLE 22a,b)**

apoA to apoB: The mean value was 0.82442(± 0.2548) and the 10th, 75th and 90th percentiles were 0.52344, 0.97453, 1.17402 respectively. A ***positive poor statistical significant association*** between apoA to apoB and age, apoA to apoB and smokers, apoA to apoB and non-smokers was found. **(TABLE 23a,b)**

DISCUSSION

In our study, which is a part of a long- term prospective investigation of association between aging and biochemical-metabolical indexes, we examined a random sample of 539 adults (519 men and 20 women). All of those were non-flying personnel of Hellenic Air Force, aging from 21 to 55 years old.

The medical examination included a complete medical history and a full physical examination; blood pressure, anthropometric measurements and information about smoking, eating, physical activity, alcohol consumption were taken. A standard panel of laboratory tests for serum chemistries was performed, including some parameters like Lp(a), CRP, which are connecting with the presence of coronary heart disease.

The mean values of these parameters were the followings: **BMI:** 25,942(±3,403), **Total cholesterol/HDL:** 5,42(±1,52), **Total cholesterol:** 217,4(± 50,48) mg%, **Triglycerides:** 121(± 101,68) mg%, **HDL:** 41.17(± 7.69) mg%, **LDL:** 151.94(± 45.51) mg%, **apoA:** 1.38(± 0.22) g/l, **apoB:** 1.12(± 0.30) g/l, **Lp(a):** 13.74(± 17.95) mg/dl, **Fibrinogen:** 258.87(± 60.95) mg/dl, **SGOT:** 26.81(± 7.39) units/l, **SGPT:** 32.71(± 17.71) units/l, **Bilirubin:** 0.69(± 0.386) mg/dl, **Sodium:** 143.85(± 2.23) mEq/l, **Potassium:** 4.395(± 0.351) mEq/l, **Urea:** 32.44(± 7.69) mg/dl, **Creatinine:** 0.937(± 0.155) mg/dl, **Glucose:** 87.61(± 10.11) mg/dl, **CRP:** 3.948(± 2.236) mg/dl, **apoA to apoB:** 0.82442(± 0.2548)

Comparing our findings with those of a previous research concerning 1164 pilots of Hellenic Air Force, we found that there is a decline of HDL cholesterol regarding the non-flying personnel.

In our Aviation Center has been established annual tests for the operational employees (pilots, crewmembers, air traffic controllers etc.) and 2-year tests for the non-operational employees (desk officers, ground crewmembers etc.).

The medical examination includes a complete medical history, a full physical examination, as well as in areas of neurology, ENT, dental, ophthalmology and psychiatry; blood pressure and anthropometric measurements and information about smoking, eating, physical activity, alcohol consumption is taken.

The results are announced to both the individual and the Health Department and actions are taken when necessary.

When BMI is over 27, a nutritional and exercise schedule is provided from "the Department of Nutrition and Exercise" and a re-examination after 3-6 months (depending the degree of overweighting and the presence of others coronary risk factors) is arranged to estimate the results. If there is no amelioration, there is one more examination after 3-6 months following the provided schedule (whenever necessary changes are made) and then, the person is relieved from his duties until the weight-target is achieved. A few time ago, the above department started a program of measuring the body fat, so as to be more objective about his results.

Concerning serum total cholesterol, when it is >300 mg% without the presence of other risk factors for CHD, or >250 mg% when there are other risk factors, we begin dietary therapy for 3-6 months. If the levels of serum cholesterol remain high after an adequate trial of dietary therapy, then we begin drug therapy with bile acid-binding resins, like **cholestyramine** (Questran) to reach goal levels. There is a little time that a study has begun about the use of **pravastatin** as a first-line drug therapy.

CONCLUSIONS

The results of our study show a ***positive statistical significant association*** between alcohol (only for smokers), BMI, total cholesterol/HDL, total cholesterol, triglycerides, HDL (only for non-smokers), LDL, apoA, apoB, fibrinogen (only for smokers), potassium (only for smokers), urea (only for smokers), glucose and age. There is a ***negative statistical significant association*** between exercise and age. We didn't find ***any statistical significant correlation*** between Lp(a), SGOT, SGPT, bilirubin, sodium, creatinine, CRP and age.

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ATTACHEMENTS

TABLE 1a

REGRESSION

Correlations

		SMOKE	AGE
Pearson Correlation	SMOKE	1,000	**0,029**
	AGE	0,029	1,000
Sig. (1-tailed)	SMOKE	,	**0,248**
	AGE	0,248	,
N	SMOKE	539	539
	AGE	539	539

TABLE 1b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of smoking by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	0,47	0,50	5,21E-02	1	0	0	1	1
26-30	129	0,50	0,50	4,42E-02	1	0	0	1	1
31-35	95	0,45	0,50	5,13E-02	1	0	0	1	1
36-40	123	0,49	0,50	4,53E-02	1	0	0	1	1
41-45	56	0,61	0,49	6,59E-02	1	0	0	1	1
46-50	30	0,50	0,51	9,28E-02	1	0	0	1	1
51-55	13	0,50	0,52	0,15	1	0	0	1	1
Total	539	0,50	0,50	2,16E-02	1	0	0	1	1

TABLE 2a

REGRESSION

Correlations

		EXERCISE	AGE
Pearson Correlation	EXERCISE	1,000	**-0,155**
	AGE	-0,155	1,000
Sig. (1-tailed)	EXERCISE	,	**0,000**
	AGE	0,000	,
N	EXERCISE	539	539
	AGE	539	539

Selecting only cases for which **Smoke=Smokers**

		EXERCISE	AGE
Pearson Correlation	EXERCISE	1,000	**0,196**
	AGE	0,196	1,000
Sig. (1-tailed)	EXERCISE	,	**0,001**
	AGE	0,001	,
N	EXERCISE	268	268
	AGE	268	268

Selecting only cases for which **Smoke= Non Smokers**

		EXERCISE	AGE
Pearson Correlation	EXERCISE	1,000	**-0,109**
	AGE	-0,109	1,000
Sig. (1-tailed)	EXERCISE	,	**0,036**
	AGE	0,036	,
N	EXERCISE	271	271
	AGE	271	271

TABLE 2b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of exercise by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	2,5269	1,4491	0,1503	5	0	1	4	4,6
26-30	129	2,0155	1,5051	0,1325	5	0	0	3	4
31-35	95	1,8526	1,4438	0,1481	5	0	0	3	4
36-40	123	1,6179	1,3276	0,1197	5	0	0	2	4
41-45	56	1,6607	1,5407	0,2059	5	0	0	3	4
46-50	30	1,900	1,4468	0,2641	5	0	0	3,25	4
51-55	13	2,000	1,7581	0,5075	5	0	0	3,75	4,7
Non smokers	271	2,0037	1,4644	8,896E-02	5	0			
Smokers	268	1,8764	1,4879	9,106E-02	5	0			
Total	539	1,9405	1,4761	6,364E-02	5	0	0	3	4

TABLE 3a

REGRESSION
Correlations

		ALCOHOL	AGE
Pearson Correlation	**ALCOHOL**	1,000	**0,079**
	AGE	0,079	1,000
Sig. (1-tailed)	**ALCOHOL**	,	**0,033**
	AGE	0,033	,
N	**ALCOHOL**	539	539
	AGE	539	539

Selecting only cases for which **Smoke=Smokers**

		ALCOHOL	AGE
Pearson Correlation	**ALCOHOL**	1,000	**0,124**
	AGE	0,124	1,000
Sig. (1-tailed)	**ALCOHOL**	,	**0,022**
	AGE	0,022	,
N	**ALCOHOL**	268	268
	AGE	268	268

Selecting only cases for which **Smoke= Non Smokers**

		ALCOHOL	AGE
Pearson Correlation	**ALCOHOL**	1,000	**0,022**
	AGE	0,022	1,000
Sig. (1-tailed)	**ALCOHOL**	,	**0,359**
	AGE	0,359	,
N	**ALCOHOL**	271	271
	AGE	271	271

TABLE 3b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of alcohol by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	1,1613	0,8759	9,083E-02	3	0	0	2	2
26-30	129	1,1473	0,8848	7,790E-02	4	0	0	2	2
31-35	95	1,2526	0,9450	9,695E-02	4	0	0	2	2
36-40	123	1,1870	0,8994	8,110E-02	4	0	0	2	2
41-45	56	1,4286	0,9697	0,1296	3	0	0	2	3
46-50	30	1,5333	0,6814	0,1244	3	1	0	2	2,9
51-55	13	1,0833	0,9003	0,2599	3	0	0	1,75	2,7
Non smokers	271	1,0959	0,8509	5,169E-02	4	0			
Smokers	268	1,3596	0,9288	5,684E-02	4	0			
Total	539	1,2268	0,8993	3,877E-02	4	0	0	2	2

TABLE 4a

REGRESSION
Correlations

		BMI	AGE
Pearson Correlation	**BMI**	1,000	**0,197**
	AGE	0,197	1,000
Sig. (1-tailed)	**BMI**	,	**0,000**
	AGE	0,000	,
N	**BMI**	539	539
	AGE	539	539

Selecting only cases for which **Smoke=Smokers**

		BMI	AGE
Pearson Correlation	**BMI**	1,000	**0,211**
	AGE	0,211	1,000
Sig. (1-tailed)	**BMI**	,	**0,000**
	AGE	0,000	,
N	**BMI**	268	268
	AGE	268	268

Selecting only cases for which **Smoke= Non Smokers**

		BMI	AGE
Pearson Correlation	**BMI**	1,000	**0,183**
	AGE	0,183	1,000
Sig. (1-tailed)	**BMI**	,	**0,001**
	AGE	0,001	,
N	**BMI**	271	271
	AGE	271	271

TABLE 4b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10^{th}, 75^{th}, and 90^{th} percentiles of BMI by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	24,6732	2,722	0,282	35,8	18,7	21,782	25,88	27,724
26-30	129	25,7755	2,822	0,248	34,2	19,8	22,16	27,81	29,41
31-35	95	26,3435	3,532	0,362	38,1	16,8	22,22	28,14	31,04
36-40	123	25,8637	4,229	0,381	32,5	17,1	22,504	27,53	29,672
41-45	56	27,1941	2,998	0,401	39,3	22,8	24,011	28,8975	31,012
46-50	30	26,6243	3,11	0,568	33,2	20,3	22,807	28,96	31,095
51-55	13	27,6625	2,728	0,787	32,7	23,7	23,924	29,9275	32,001
Non Smokers	271	25,926	3,395	0,206	39,3	16,8			
Smokers	268	25,96	3,417	0,209	34,9	18,7			
Total	539	25,942	3,403	0,147	39,3	16,8	22,526	27,77	29,83

TABLE 5a

REGRESSION

Correlations

		Total chol/HDL	AGE
Pearson Correlation	**Total chol/HDL**	1,000	**0,269**
	AGE	0,269	1,000
Sig. (1-tailed)	**Total chol/HDL**	,	**0,000**
	AGE	0,000	,
N	**Total chol/HDL**	539	539
	AGE	539	539

Selecting only cases for which **Smoke=Smokers**

		Total chol/HDL	AGE
Pearson Correlation	**Total chol/HDL**	1,000	**0,301**
	AGE	0,301	1,000
Sig. (1-tailed)	**Total chol/HDL**	,	**0,000**
	AGE	0,000	,
N	Total chol/HDL	268	268
	AGE	268	268

Selecting only cases for which **Smoke= Non Smokers**

		Total chol/HDL	AGE
Pearson Correlation	**Total chol/HDL**	1,000	**0,228**
	AGE	0,228	1,000
Sig. (1-tailed)	**Total chol/HDL**	,	**0,000**
	AGE	0,000	,
N	**Total chol/HDL**	271	271
	AGE	271	271

TABLE 5b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10^{th}, 75^{th}, and 90^{th} percentiles of total cholesterol/HDL by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	4,66	1,33	0,14	8	2	3,312	5,33	6,602
26-30	129	5,18	1,41	0,12	11	2	3,57	5,79	7
31-35	95	5,53	1,5	0,15	9	3	3,85	6,39	7,574
36-40	123	5,78	1,57	0,14	11	3	3,97	6,61	7,726
41-45	56	6,06	1,6	0,21	12	3	4,428	6,985	8,629
46-50	30	5,75	1,24	0,23	8	3	4,21	6,94	7,3
51-55	13	5,73	1,54	0,44	8	3	3,528	7,075	8,085
Non Smokers	271	5,14	1,31	7,98E-02	9	2			
Smokers	268	5,72	1,66	0,1	12	3			
Total	539	5,42	1,52	6,57E-02	12	2	3,7	6,23	7,42

TABLE 6a

REGRESSION

Correlations

		Total cholesterol	AGE
Pearson Correlation	**Total cholesterol**	1,000	**0,366**
	AGE	0,366	1,000
Sig. (1-tailed)	**Total cholesterol**	,	**0,000**
	AGE	0,000	,
N	**Total cholesterol**	539	539
	AGE	539	539

.Selecting only cases for which **Smoke= Smokers**

		Total cholesterol	AGE
Pearson Correlation	**Total cholesterol**	1,000	**0,391**
	AGE	0,391	1,000
Sig. (1-tailed)	**Total cholesterol**	,	**0,000**
	AGE	0,000	,
N	**Total cholesterol**	268	268
	AGE	268	268

a.Selecting only cases for which **Smoke= NonSmokers**

		Total cholesterol	AGE
Pearson Correlation	**Total cholesterol**	1,000	**0,337**
	AGE	0,337	1,000
Sig. (1-tailed)	**Total cholesterol**	,	**0,000**
	AGE	0,000	,
N	**Total cholesterol**	271	271
	AGE	271	271

TABLE 6b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of total cholesterol by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	182,9	47,43	4,92	317	101	132	207,5	250,4
26-30	129	209,81	48,29	4,25	338	100	155	242,5	274
31-35	95	220,05	47,3	4,85	338	106	162,4	249	285
36-40	123	228,01	46,55	4,2	359	126	165	259	288
41-45	56	253,95	46,1	6,16	385	160	197,4	280,5	310,1
46-50	30	231,33	34,15	6,23	304	161	187	246,75	286,8
51-55	13	231,5	44,50	12,84	333	164	169,7	260,75	314,1
Non smokers	271	212,27	48,55	2,95	338	106			
Smokers	268	222,62	51,93	3,18	385	101			
Total	539	217,41	50,48	2,18	385	100	155,9	251	283,2

TABLE 7a

REGRESSION

Correlations

		Triglykerides	AGE
Pearson Correlation	**Triglykerides**	1,000	**0,177**
	AGE	0,177	1,000
Sig. (1-tailed)	**Triglykerides**	,	**0,000**
	AGE	0,000	,
N	**Triglykerides**	539	539
	AGE	539	539

Selecting only cases for which **Smoke=Smokers**

		Triglykerides	AGE
Pearson Correlation	**Triglykerides**	1,000	**0,206**
	AGE	0,206	1,000
Sig. (1-tailed)	**Triglykerides**	,	**0,000**
	AGE	0,000	,
N	**Triglykerides**	268	268
	AGE	268	268

Selecting only cases for which **Smoke= Non Smokers**

		Triglykerides	AGE
Pearson Correlation	**Triglykerides**	1,000	**0,133**
	AGE	0,133	1,000
Sig. (1-tailed)	**Triglykerides**	,	**0,014**
	AGE	0,014	,
N	**Triglykerides**	271	271
	AGE	271	271

TABLE 7b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of triglykerides by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	89,66	75,85	7,87	410	22	27,4	116,5	169,4
26-30	129	111,14	102,78	9,05	886	20	32	147	205
31-35	95	127,89	106,01	10,88	854	25	42,2	149	225,2
36-40	123	130,08	100,51	9,06	734	24	37,2	171	240
41-45	56	145,73	129,32	17,28	913	28	39,7	170,75	262,9
46-50	30	142,67	78,69	14,37	315	25	50	197,5	280,6
51-55	13	152,75	96,76	27,93	400	80	81,2	183,25	364,3
Non smokers	271	104,45	85,38	5,19	886	20			
Smokers	268	137,8	113,62	6,95	913	25			
Total	539	121,00	101,68	4,38	913	20	35	154	228

TABLE 8a

REGRESSION

Correlations

		HDL	AGE
Pearson Correlation	**HDL**	1,000	**0,063**
	AGE	0,063	1,000
Sig. (1-tailed)	**HDL**	,	**0,072**
	AGE	0,072	,
N	**HDL**	539	539
	AGE	539	539

Selecting only cases for which **Smoke=Smokers**

		HDL	AGE
Pearson Correlation	**HDL**	1,000	**0,048**
	AGE	0,048	1,000
Sig. (1-tailed)	**HDL**	,	**0,216**
	AGE	0,216	,
N	**HDL**	268	268
	AGE	268	268

Selecting only cases for which **Smoke= Non Smokers**

		HDL	AGE
Pearson Correlation	**HDL**	1,000	**0,089**
	AGE	0,089	1,000
Sig. (1-tailed)	**HDL**	,	**0,073**
	AGE	0,073	,
N	**HDL**	271	271
	AGE	271	271

TABLE 8b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of HDL by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	40,09	6,33	0,66	65	28	32,4	42	47
26-30	129	41,73	8,61	0,76	90	24	33	46	51
31-35	95	40,84	6,93	0,71	61	25	32,6	44	49
36-40	123	40,73	7,71	0,69	71	29	32	44	51
41-45	56	42,93	7,35	0,98	68	27	33,7	45,75	50,3
46-50	30	41,23	8,58	1,57	72	26	32,1	43	50
51-55	13	42,33	11,10	3,20	68	30	30,3	47,75	63,5
Non smokers	271	42,28	7,64	0,46	71	25			
Smokers	268	40,05	7,59	0,46	90	24			
Total	539	41,17	7,69	0,33	90	24	32,00	45,00	51,00

TABLE 9a

REGRESSION

Correlations

		LDL	AGE
Pearson Correlation	**LDL**	1,000	**0,312**
	AGE	0,312	1,000
Sig. (1-tailed)	**LDL**	,	**0,000**
	AGE	0,000	,
N	**LDL**	539	539
	AGE	539	539

Selecting only cases for which Smoke=Smokers

		LDL	AGE
Pearson Correlation	**LDL**	1,000	**0,313**
	AGE	0,313	1,000
Sig. (1-tailed)	**LDL**	,	**0,000**
	AGE	0,000	,
N	**LDL**	268	268
	AGE	268	268

. Selecting only cases for which Smoke= Non Smokers

		LDL	AGE
Pearson Correlation	**LDL**	1,000	**0,309**
	AGE	0,309	1,000
Sig. (1-tailed)	**LDL**	,	**0,000**
	AGE	0,000	,
N	**LDL**	271	271
	AGE	271	271

TABLE 9b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of LDL by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	125,38	42,27	4,38	256	55	77,2	144,9	184,28
26-30	129	146,88	44,43	3,91	273	53	92	176,3	212,6
31-35	95	151,56	45,21	4,64	257	50	88,88	178,2	215,56
36-40	123	160,51	43,00	3,88	279	51	106,32	189,6	218,64
41-45	56	181,65	40,36	5,39	288	113	136,78	207,5	241,01
46-50	30	164,65	33,01	6,03	236	99	126,88	181,7	217,24
51-55	44,1413	156,95	46,42	13,4	263	80	88,46	176,25	241,68
Non smokers	271	149,74	44,14	2,68	273	53			
Smokers	268	154,18	46,84	2,87	288	51			
Total	539	151,94	45,51	1,96	288	50	93,98	178,9	213,55

TABLE 10a

REGRESSION

Correlations

		apoA	AGE
Pearson Correlation	**apoA**	1,000	**0,099**
	AGE	0,099	1,000
Sig. (1-tailed)	**apoA**	,	**0,011**
	AGE	0,011	,
N	**apoA**	539	539
	AGE	539	539

Selecting only cases for which Smoke=Smokers

		apoA	AGE
Pearson Correlation	**apoA**	1,000	**0,128**
	AGE	0,128	1,000
Sig. (1-tailed)	**apoA**	,	**0,018**
	AGE	0,018	,
N	**apoA**	268	268
	AGE	268	268

Selecting only cases for which Smoke= Non Smokers

		apoA	AGE
Pearson Correlation	**apoA**	1,000	**0,084**
	AGE	0,084	1,000
Sig. (1-tailed)	**apoA**	,	**0,084**
	AGE	0,084	,
N	**apoA**	271	271
	AGE	271	271

TABLE 10b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of apoA by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	1,35	0,20	2,06E-02	1,601	0,974	1,1162	1,4380	1,6288
26-30	129	1,36	0,20	1,80E-02	1,653	0,832	1,0880	1,4715	1,6210
31-35	95	1,40	0,22	2,22E-02	1,761	0,922	1,1014	1,5630	1,6530
36-40	123	1,38	0,22	2,03E-02	2,172	1,023	1,1090	1,4980	1,6770
41-45	56	1,43	0,28	3,71E-02	2,22	1,2	1,2221	1,5643	1,7779
46-50	30	1,41	0,25	4,48E-02	1,954	1,154	1,0596	1,5120	1,7514
51-55	13	1,44	0,20	5,70E-02	1,856	1,256	1,0973	1,6288	1,6744
Non smokers	271	1,42	0,23	1,41E-02	1,856	0,974			
Smokers	268	1,35	0,22	1,25E-02	2,22	0,832			
Total	539	1,38	0,22	9,56E-03	2,22	0,832	1,11	1,51	1,66

TABLE 11a

REGRESSION

Correlations

		apoB	AGE
Pearson Correlation	**apoB**	1,000	**0,339**
	AGE	0,339	1,000
Sig. (1-tailed)	**apoB**	,	**0,000**
	AGE	0,000	,
N	**apoB**	539	539
	AGE	539	539

Selecting only cases for which **Smoke=Smokers**

		apoB	AGE
Pearson Correlation	**apoB**	1,000	**0,274**
	AGE	0,274	1,000
Sig. (1-tailed)	**apoB**	,	**0,000**
	AGE	0,000	,
N	**apoB**	268	268
	AGE	268	268

Selecting only cases for which **Smoke= Non Smokers**

		apoB	AGE
Pearson Correlation	**apoB**	1,000	**0,403**
	AGE	0,403	1,000
Sig. (1-tailed)	**apoB**	,	**0,000**
	AGE	0,000	,
N	**apoB**	271	271
	AGE	271	271

TABLE 11b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of apoB by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	0,92	0,28	2,89E-02	1,451	0,605	0,6208	1,0695	1,2454
26-30	129	1,08	0,30	2,66E-02	1,437	0,742	0,7243	1,2760	1,4578
31-35	95	1,11	0,27	2,81E-02	1,478	0,703	0,7462	1,2890	1,5002
36-40	123	1,20	0,28	2,53E-02	1,481	0,653	0,8434	1,4280	1,5292
41-45	56	1,30	0,29	3,84E-02	1,954	0,795	1,0333	1,5175	1,6301
46-50	30	1,20	0,25	4,64E-02	1,652	0,438	0,7695	1,3378	1,5519
51-55	13	1,17	0,27	7,66E-02	1,730	0,42	0,8193	1,3880	1,5937
Non smokers	271	1,06	0,3	1,81E-02	1,481	0,406			
Smokers	268	1,17	0,3	1,83E-02	1,437	0,42			
Total	539	1,12	0,30	1,31E-02	1,437	0,406	0,74	1,32	1,52

TABLE 12a

REGRESSION

Correlations

		LP(a)	AGE
Pearson Correlation	LP(a)	1,000	**-0,035**
	AGE	-0,035	1,000
Sig. (1-tailed)	LP(a)	,	**0,211**
	AGE	0,211	,
N	LP(a)	539	539
	AGE	539	539

Selecting only cases for which Smoke=Smokers

		LP(a)	AGE
Pearson Correlation	LP(a)	1,000	**-0,022**
	AGE	-0,022	1,000
Sig. (1-tailed)	LP(a)	,	**0,357**
	AGE	0,357	,
N	LP(a)	268	268
	AGE	268	268

Selecting only cases for which Smoke= Non Smokers

		LP(a)	AGE
Pearson Correlation	LP(a)	1,000	**-0,044**
	AGE	-0,044	1,000
Sig. (1-tailed)	LP(a)	,	**0,235**
	AGE	0,235	,
N	LP(a)	271	271
	AGE	271	271

TABLE 12b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of LP(a) by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	15,32	19,75	2,05	102	1	2,5	19,4	46,9
26-30	129	12,58	16,89	1,49	97	1	2,5	14,4	36,3
31-35	95	15,54	19,22	1,97	116	1	2,5	22,9	39,2
36-40	123	13,22	18,39	1,66	128	2	2,5	14,8	31,42
41-45	56	13,88	17,04	2,28	106	1	2,5	16	33,26
46-50	30	10,46	13,80	2,52	70	3	2,5	11,45	30,45
51-55	13	12,44	13,58	3,92	50	3	2,5	18,53	41,44
Non smokers	271	14,57	18,2	1,11	116	1			
Smokers	268	12,89	17,69	1,08	128	1			
Total	539	13,74	17,95	0,77	128	1	2,5	15,48	36,63

TABLE 13a

REGRESSION

Correlations

		FIBRINOGEN	AGE
Pearson Correlation	FIBRINOGEN	1,000	**0,132**
	AGE	0,132	1,000
Sig. (1-tailed)	FIBRINOGEN	,	**0,001**
	AGE	0,001	,
N	FIBRINOGEN	539	539
	AGE	539	539

Selecting only cases for which Smoke=Smokers

		FIBRINOGEN	AGE
Pearson Correlation	FIBRINOGEN	1,000	**0,197**
	AGE	0,197	1,000
Sig. (1-tailed)	FIBRINOGEN	,	**0,001**
	AGE	0,001	,
N	FIBRINOGEN	268	268
	AGE	268	268

Selecting only cases for which Smoke= Non Smokers

		FIBRINOGEN	AGE
Pearson Correlation	FIBRINOGEN	1,000	**0,045**
	AGE	0,045	1,000
Sig. (1-tailed)	FIBRINOGEN	.,	**0,228**
	AGE	0,228	,
N	FIBRINOGEN	271	271
	AGE	271	271

TABLE 13b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of fibrinogen by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	243,22	53,8	5,58	488	170	199,4	265,5	310,2
26-30	129	256,85	60,83	5,36	507	171	206	281	329
31-35	95	253,26	54,56	5,60	460	173	207,8	281	323,4
36-40	123	269,81	73,18	6,60	632	181	210,4	302	353,58
41-45	56	269,38	54	7,22	460	177	218	289,75	322,7
46-50	30	265,97	50,67	9,25	375	171	218,6	309	361,4
51-55	13	267,17	58,07	16,76	383	185	192,8	305,5	370,7
Non smokers	271	249,14	54,15	3,29	461	173			
Smokers	268	268,74	65,79	4,03	632	170			
Total	539	258,87	60,95	2,63	632	170	206	282,25	327,1

TABLE 14a

REGRESSION

Correlations

		SGOT	AGE
Pearson Correlation	**SGOT**	1,000	**-0,016**
	AGE	-0,016	1,000
Sig. (1-tailed)	**SGOT**	,	**0,355**
	AGE	0,355	,
N	**SGOT**	539	539
	AGE	539	539

Selecting only cases for which **Smoke=Smokers**

		SGOT	AGE
Pearson Correlation	**SGOT**	1,000	**-0,030**
	AGE	-0,030	1,000
Sig. (1-tailed)	**SGOT**	,	**0,311**
	AGE	0,311	,
N	**SGOT**	268	268
	AGE	268	268

Selecting only cases for which **Smoke= Non Smokers**

		SGOT	AGE
Pearson Correlation	**SGOT**	1,000	**0,001**
	AGE	0,001	1,000
Sig. (1-tailed)	**SGOT**	,	**0,492**
	AGE	0,492	,
N	**SGOT**	271	271
	AGE	271	271

TABLE 14b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of SGOT by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	26,58	9,09	0,94	84	13	19	29	34
26-30	129	27	8,07	0,71	62	16	20	30	36
31-35	95	27,51	8,05	0,83	62	12	18	31	38,4
36-40	123	26,9	5,82	0,52	53	14	20,4	29	34,6
41-45	56	25,46	4,96	0,66	40	14	20	28	32,6
46-50	30	26,1	5,26	0,96	40	15	20,20	28,25	32,9
51-55	13	28,17	8,76	2,53	46	19	19,6	29	45,7
Non smokers	271	27,19	7,48	0,45	62	12			
Smokers	268	26,43	7,3	0,45	84	14			
Total	539	26,81	7,39	0,32	84	12	20	29	34,1

TABLE 15a

REGRESSION

Correlations

		SGPT	AGE
Pearson Correlation	**SGPT**	1,000	**-0,012**
	AGE	-0,012	1,000
Sig. (1-tailed)	**SGPT**	,	**0,386**
	AGE	0,386	,
N	**SGPT**	539	539
	AGE	539	539

Selecting only cases for which **Smoke=Smokers**

		SGPT	AGE
Pearson Correlation	**SGPT**	1,000	**0,006**
	AGE	0,006	1,000
Sig. (1-tailed)	**SGPT**	,	**0,460**
	AGE	0,460	,
N	**SGPT**	268	268
	AGE	268	268

Selecting only cases for which **Smoke= Non Smokers**

		SGPT	AGE
Pearson Correlation	**SGPT**	1,000	**-0,030**
	AGE	-0,030	1,000
Sig. (1-tailed)	**SGPT**	,	**0,311**
	AGE	0,311	,
N	**SGPT**	271	271
	AGE	271	271

TABLE 15b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of SGPT by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	30,89	20,67	2,14	144	11	17	34,5	51
26-30	129	33,01	18,81	1,66	111	10	16	39,5	54
31-35	95	37,15	20,36	2,09	105	11	17,6	49	69,8
36-40	123	32,59	14,29	1,29	95	14	19,4	40	46,6
41-45	56	29,55	11,62	1,55	69	12	17,4	34	43,6
46-50	30	30,90	16,64	3,04	97	16	18	31,5	51,8
51-55	13	28,92	11,41	3,29	56	16	16,6	34,5	52,1
Non smokers	271	32,76	18,46	1,12	131	10			
Smokers	268	32,66	16,96	1,04	144	11			
Total	539	32,71	17,71	0,76	144	10	17,9	39,25	53

TABLE 16a

REGRESSION

Correlations

		Total bilirubin	AGE
Pearson Correlation	**total bilirubin**	1,000	**0,005**
	AGE	0,005	1,000
Sig. (1-tailed)	**total bilirubin**	,	**0,455**
	AGE	0,455	,
N	**total bilirubin**	539	539
	AGE	539	539

Selecting only cases for which **Smoke=Smokers**

		Total bilirubin	AGE
Pearson Correlation	**total bilirubin**	1,000	**0,039**
	AGE	0,039	1,000
Sig. (1-tailed)	**total bilirubin**	,	**0,264**
	AGE	0,264	,
N	**total bilirubin**	268	268
	AGE	268	268

Selecting only cases for which **Smoke= Non Smokers**

		Total bilirubin	AGE
Pearson Correlation	**total bilirubin**	1,000	**-0,020**
	AGE	-0,020	1,000
Sig. (1-tailed)	**total bilirubin**	,	**0,370**
	AGE	0,370	,
N	**total bilirubin**	271	271
	AGE	271	271

TABLE 16b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of bilirubin by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	0,735	0,458	4,749E-02	2,9	0,1	0,4	0,9	1,16
26-30	129	0,681	0,406	3,578E-02	2,6	0,1	0,3	0,85	1,2
31-35	95	0,66	0,325	3,338E-02	1,7	0,1	0,3	0,9	1,1
36-40	123	0,67	0,398	3,584E-02	2,1	0,1	0,3	0,8	1,2
41-45	56	0,675	0,297	3,965E-02	1,6	0,1	0,37	0,8	1,03
46-50	30	0,747	0,316	5,768E-02	1,5	0,3	0,41	1	1,3
51-55	13	0,8	0,449	0,130	1,9	0,4	0,4	1	1,75
Non smokers	271	0,72	0,417	2,532E-02	2,9	0,1			
Smokers	268	0,659	0,351	2,15E-02	2,6	0,1			
Total	539	0,69	0,386	1,666E-03	2,9	0,1	0,3	0,9	1,2

TABLE 17a

REGRESSION

Correlations

		Na	AGE
Pearson Correlation	**Na**	1,000	**-0,035**
	AGE	-0,035	1,000
Sig. (1-tailed)	**Na**	,	**0,212**
	AGE	0,212	,
N	**Na**	539	539
	AGE	539	539

Selecting only cases for which **Smoke=Smokers**

		Na	AGE
Pearson Correlation	**Na**	1,000	**-0,015**
	AGE	-0,015	1,000
Sig. (1-tailed)	**Na**	,	**0,407**
	AGE	0,407	,
N	**Na**	268	268
	AGE	268	268

Selecting only cases for which **Smoke= Non Smokers**

		Na	AGE
Pearson Correlation	**Na**	1,000	**-0,056**
	AGE	-0,056	1,000
Sig. (1-tailed)	**Na**	,	**0,181**
	AGE	0,181	,
N	**Na**	271	271
	AGE	271	271

TABLE 17b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of sodium by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	144,09	1,84	0,19	149	140	142	145	146
26-30	129	143,88	2,26	0,20	151	139	141	145	147
31-35	95	143,65	2,11	0,22	148	138	140,6	145	146
36-40	123	143,93	2,32	0,21	149	137	141	146	147
41-45	56	143,59	2,66	0,36	150	136	140,7	145	147
46-50	30	143,70	2,53	0,46	150	139	141	145	147,9
51-55	13	144,17	1,70	0,49	147	141	141,3	145	146,7
Non smokers	271	143,8	2,28	0,14	151	137			
Smokers	268	143,9	2,18	0,13	151	138			
Total	539	143,85	2,23	9,60E-02	151	137	141	145	147

TABLE 18a

REGRESSION
Correlations

		K	AGE
Pearson Correlation	**K**	1,000	**0,055**
	AGE	0,055	1,000
Sig. (1-tailed)	**K**	,	**0,102**
	AGE	0,102	,
N	**K**	539	539
	AGE	539	539

Selecting only cases for which Smoke=Smokers

		K	AGE
Pearson Correlation	**K**	1,000	**-0,022**
	AGE	-0,022	1,000
Sig. (1-tailed)	**K**	,	**0,357**
	AGE	0,357	,
N	**K**	268	268
	AGE	268	268

Selecting only cases for which Smoke= Non Smokers

		K	AGE
Pearson Correlation	**K**	1,000	**0,101**
	AGE	0,101	1,000
Sig. (1-tailed)	**K**	,	**0,049**
	AGE	0,049	,
N	**K**	271	271
	AGE	271	271

TABLE 18b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of potassium by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	4,343	0,346	3,584E-02	5,3	3,6	3,94	4,6	4,86
26-30	129	4,413	0,357	3,143E-02	5,6	3,7	4	4,6	5
31-35	95	4,396	0,348	3,570E-02	5,1	3,7	4	4,6	4,9
36-40	123	4,410	0,362	3,266E-02	5,7	3,7	3,94	4,6	4,9
41-45	56	4,345	0,332	4,442E-02	5,2	3,7	4	4,5	4,83
46-50	30	4,443	0,309	5,646E-02	5,0	3,9	4,01	4,625	4,99
51-55	13	4,558	0,421	0,122	5,4	3,9	3,99	4,85	5,31
Non smokers	271	4,341	0,35	2,129E-02	5,4	3,6			
Smokers	268	4,449	0,345	2,11E-02	5,7	3,7			
Total	539	4,395	0,351	1,515E-02	5,7	3,6	4	4,6	4,9

TABLE 19a

REGRESSION
Correlations

		UREA	AGE
Pearson Correlation	**UREA**	1,000	**0,053**
	AGE	0,053	1,000
Sig. (1-tailed)	**UREA**	,	**0,108**
	AGE	0,108	,
N	**UREA**	539	539
	AGE	539	539

Selecting only cases for which Smoke=Smokers

		UREA	AGE
Pearson Correlation	**UREA**	1,000	**0,091**
	AGE	0,091	1,000
Sig. (1-tailed)	**UREA**	,	**0,069**
	AGE	0,069	,
N	**UREA**	268	268
	AGE	268	268

Selecting only cases for which Smoke= Non Smokers

		UREA	AGE
Pearson Correlation	**UREA**	1,000	**0,016**
	AGE	0,016	1,000
Sig. (1-tailed)	**UREA**	,	**0,395**
	AGE	0,395	,
N	**UREA**	271	271
	AGE	271	271

TABLE 19b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of urea by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	33,30	6,75	0,70	53	18	25	36,5	42,5
26-30	129	31,14	7,18	0,63	51	14	22	35	42
31-35	95	32,43	7,46	0,77	53	18	22	37	44,4
36-40	123	32,46	7,64	0,69	53	10	24	37	43
41-45	56	32,82	8,35	1,12	58	15	21,7	37,75	45
46-50	30	33,13	9,23	169	63	21	23	38	43,5
51-55	13	36,25	12,79	3,69	70	23	23,3	38,5	63,7
Non smokers	271	32,63	7,71	0,47	63	10			
Smokers	268	32,26	7,67	0,47	70	15			
Total	539	32,44	7,69	0,33	70	10	23	37	43

TABLE 20a

REGRESSION

Correlations

		CREATININE	AGE
Pearson Correlation	**CREATININE**	1,000	**-0,008**
	AGE	-0,008	1,000
Sig. (1-tailed)	**CREATININE**	,	**0,423**
	AGE	0,423	,
N	**CREATININE**	539	539
	AGE	539	539

Selecting only cases for which Smoke=Smokers

		CREATININE	AGE
Pearson Correlation	**CREATININE**	1,000	**-0,015**
	AGE	-0,015	1,000
Sig. (1-tailed)	**CREATININE**	,	**0,405**
	AGE	0,405	,
N	**CREATININE**	268	268
	AGE	268	268

Selecting only cases for which Smoke= Non Smokers

		CREATININE	AGE
Pearson Correlation	**CREATININE**	1,000	**-0,003**
	AGE	-0,003	1,000
Sig. (1-tailed)	**CREATININE**	,	**0,478**
	AGE	0,478	,
N	**CREATININE**	271	271
	AGE	271	271

TABLE 20b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of creatinine by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	0,939	0,150	1,559E-02	1,3	0,2	0,8	1	1,1
26-30	129	0,941	0,142	1,253E-02	1,3	0,5	0,8	1	1,1
31-35	95	0,935	0,19	1,524E-02	1,4	0,4	0,8	1	1,1
36-40	123	0,932	0,159	1,434E-02	1,5	0,6	0,7	1	1,1
41-45	56	0,950	0,189	2,523E-02	1,9	0,6	0,8	1	1,1
46-50	30	0,923	0,136	2,523E-02	1,3	0,7	0,8	1	1,1
51-55	13	0,925	0,218	6,292E-02	1,2	0,4	0,49	1,1	1,17
Non smokers	271	0,934	0,162	9,816E-02	1,5	0,2			
Smokers	268	0,94	0,148	9,067E-02	1,9	0,6			
Total	539	0,937	0,155	6,681E-03	1,9	0,2	0,8	1	1,1

TABLE 21a

REGRESSION

Correlations

		GLUCOSE	AGE
Pearson Correlation	**GLUCOSE**	1,000	**0,200**
	AGE	0,200	1,000
Sig. (1-tailed)	**GLUCOSE**	,	**0,000**
	AGE	0,000	,
N	**GLUCOSE**	539	539
	AGE	539	539

Selecting only cases for which **Smoke=Smokers**

		GLUCOSE	AGE
Pearson Correlation	**GLUCOSE**	1,000	**0,248**
	AGE	0,248	1,000
Sig. (1-tailed)	**GLUCOSE**	,	**0,000**
	AGE	0,000	,
N	**GLUCOSE**	268	268
	AGE	268	268

Selecting only cases for which **Smoke= Non Smokers**

		GLUCOSE	AGE
Pearson Correlation	**GLUCOSE**	1,000	**0,145**
	AGE	0,145	1,000
Sig. (1-tailed)	**GLUCOSE**	,	**0,008**
	AGE	0,008	,
N	**GLUCOSE**	271	271
	AGE	271	271

TABLE 21b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of glucose by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	85,33	9,34	0,97	108	69	73	92	100,2
26-30	129	86,67	10,22	0,90	130	47	75	92	98
31-35	95	87,17	9,57	0,98	112	62	76,6	92	102,4
36-40	123	87,36	8,69	0,78	117	64	78	92	98,6
41-45	56	90,79	9,12	1,22	121	76	78,7	96,75	101,3
46-50	30	92,83	15,06	2,75	156	71	76,2	97	105
51-55	13	93,75	13,55	3,91	119	76	77,2	99	118,1
Non smokers	271	88,14	9,04	0,55	130	65			
Smokers	268	87,09	11,08	0,68	156	47			
Total	539	87,61	10,11	0,44	156	47	76	93	101

TABLE 22a

REGRESSION

Correlations

		CRP	AGE
Pearson Correlation	**CRP**	1,000	**0,053**
	AGE	0,053	1,000
Sig. (1-tailed)	**CRP**	,	**0,108**
	AGE	0,108	,
N	**CRP**	539	539
	AGE	539	539

Selecting only cases for which **Smoke=Smokers**

		CRP	AGE
Pearson Correlation	**CRP**	1,000	**0,054**
	AGE	0,054	1,000
Sig. (1-tailed)	**CRP**	,	**0,190**
	AGE	0,190	,
N	**CRP**	268	268
	AGE	268	268

Selecting only cases for which **Smoke= Non Smokers**

		CRP	AGE
Pearson Correlation	**CRP**	1,000	**0,052**
	AGE	0,052	1,000
Sig. (1-tailed)	**CRP**	,	**0,199**
	AGE	0,199	,
N	**CRP**	271	271
	AGE	271	271

TABLE 22b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of CRP by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	3,770	2,475	0,257	20,7	1,0	3,2	3,4	3,4
26-30	129	3,871	1,606	0,141	13,9	2,0	3,2	3,4	5,4
31-35	95	4,052	2,635	0,270	23,2	1,0	3,2	3,4	6,04
36-40	123	3,930	2,431	0,219	27,1	3,2	3,2	3,4	5,16
41-45	56	4,080	2,193	0,293	12,6	1,1	3,2	3,4	7,41
46-50	30	4,393	2,065	0,377	9,3	3,2	3,2	4	9,15
51-55	13	3,800	1,205	0,348	7,4	3,2	3,2	3,925	6,53
Non smokers	271	3,87	2,417	0,147	27,1	1			
Smokers	268	4,028	2,037	0,125	20,7	1			
Total	539	3,948	2,236	9,638E-02	27,1	1,0	3,2	3,4	5,4

TABLE 23a

REGRESSION

Correlations

		apoB to apoA	AGE
Pearson Correlation	**apoB to apoA**	1,000	**0,244**
	AGE	0,244	1,000
Sig. (1-tailed)	**apoB to apoA**	,	**0,000**
	AGE	0,000	,
N	**apoB to apoA**	539	539
	AGE	539	539

Selecting only cases for which **Smoke=Smokers**

		apoB to apoA	AGE
Pearson Correlation	**apoB to apoA**	1,000	**0,285**
	AGE	0,285	1,000
Sig. (1-tailed)	**apoB to apoA**	,	**0,000**
	AGE	0,000	,
N	**apoB to apoA**	268	268
	AGE	268	268

Selecting only cases for which **Smoke= Non Smokers**

		apoB to apoA	AGE
Pearson Correlation	**apoB to apoA**	1,000	**0,196**
	AGE	0,196	1,000
Sig. (1-tailed)	**apoB to apoA**	,	**0,001**
	AGE	0,001	,
N	**apoB to apoA**	271	271
	AGE	271	271

TABLE 23b

Means, standard deviations (SD), standard errors (SEE), Maximum and Minimum values, 10th, 75th, and 90th percentiles of apoA to apoB by five-year age groups

Age groups (years)	Total no	Means	SD	SEE	Max. value	Min. value	10th	75th	90th
21-25	93	0,69509	0,22687	2,353E-02	1,426	0,162	0,4512	0,8244	0,9652
26-30	129	0,81203	0,26140	2,301E-02	1,789	0,287	0,5240	0,9689	1,1738
31-35	95	0,80725	0,22891	2,349E-02	1,462	0,301	0,4896	0,9735	1,0738
36-40	123	0,89852	0,26071	2,351E-02	1,840	0,374	0,5781	1,0780	1,2136
41-45	56	0,91213	0,26397	3,527E-02	1,466	0,170	0,6687	1,1350	1,3192
46-50	30	0,86579	0,20302	3,707E-02	1,226	0,398	0,5827	0,9856	1,1521
51-55	13	0,82360	0,18471	5,332E-02	1,184	0,589	0,5995	0,9311	1,1504
Non smokers	271	0,76162	0,22957	1,395E-02	1,509	0,162			
Smokers	268	0,88816	0,26358	1613E-02	1,840	0,319			
Total	539	0,82442	0,25480	1,099E-02	1,840	0,162	0,52344	0,97453	1,17402

Does Aging or Endothelial Dysfunction Pose a Threat to Military Crewmembers?

(October 1999)

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SUMMARY

Aging is a physiologic process associated with an increase of health conditions limiting somewhat an aviator ´s performance abilities generally. What is more, vascular aging is closely linked with an increase in cardiovascular morbidity and mortality. This may be related to cellular changes due to an increased oxidative stress or/and to an impaired release of vasoactive mediators by endothelium cells. Endothelium-dependent relaxation decreases with aging. Consequent cardiovascular changes and damages with or without the presence of other risk factors and bad life style habits may speed up that process. This may lead to clinical manifestation of the disease, grounding, treatment and even to a permanent disqualification from flying duty not surprisingly within the third and fourth decade. Besides aging, which is an independent risk factor per se, there are new scientific discoveries which have refined our understanding of the endothelium dysfunction process complexity. Additionally, it has been proven that some medicaments like HMG-CoA reductase inhibitors, ACE inhibitors and Ca antagonists, particularly those with a long duration of action, improve endothelium function of the coronary circulation in patients with atherosclerosis or hypertension along with an appropriate physical activity, smoking cessation, glucose intake restriction etc. The content of this paper is focused on highlighting new aspects of aging, links between them, mechanisms of action and interaction. The whole process should be seen as a complex of mechanical, humoral, nutritious, metabolic, endocrine and exogenous factors interplay, having a deleterious impact on human health status, crewmembers including. The end-stage occurs more earlier then simply in the course of natural aging process. Better understanding of these facts was contrasted with clinical findings among the group of Czech military aviators primarily treated for hypertension, as well as for hyperlipidemia and hyperuricemia over the past five years. We succeeded in good control of hypertension pharmacologically, but we failed with influencing of other discovered risk factors. No wonder, that prior to ending up this study, three aviators were disqualified for flying duty due to coronary artery disease (CAD) development. Based on comparison of known experimental facts, clinical trial outcomes and our findings, we have tried to formulate possible pathways for changing our minds and defined particular steps in order to reverse the unwanted trends reached so far in the management of cardiovascular diseases. These steps consist of non-pharmacological and pharmacological interventions in crewmembers. The answer to the question at the beginning will be more elucidated and sophisticated steps then formulated at the end of this paper.

INTRODUCTION

The health status worsens with aging and there is an increase in conditions limiting aviator ´s performance ability. The opposite state, marked as vitality of an individual, can be defined as a summation of all functional capacities of his important organs and homeostatic systems that are essential for his survival. Human functional capacity is supposed to decline with aging roughly linearly at about 1% per year after the age of 30 in male subjects despite the fact, that literature increasingly supports the argument, that declining trends in CAD mortality reflect changes in cardiac risk factors identification and modification (4). It has become apparent, that the policy of primary prevention should have been instituted in the aviators population more vigorously then it has been done so far (20). Relationship between

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increasing cardiac risk and age have been shown in Framingham (5,7,10,14) as well as in other previous studies (24, 29). Although the death rate for CAD has been declining by approx. 2-3% per year for the past 15 years, it still remains an important cause of morbidity and death (10,24). When looking back at the categories of medical conditions which have most often been responsible for permanent disqualification of flying personnel, cardiovascular diseases as a category were found the commonest ones – precisely in 30% (29). The first and second place most frequent diseases were CAD and hypertension, each accounting for 10%, third and fourth position were placed by spinal disorders and diabetes mellitus. These illnesses were found predominantly in the over-40 years age category. In the lower age categories the prevalence was lower (29) . Based on these references and on data obtained from current observational studies among USAF and Czech waivered aviators for different chronic illnesses, hypertension was the most frequent cause for non and pharmacological interventions (26). It has been discovered an increase in metabolic disorders in both countries as well (25,26).

Since that time when risk factors for CAD have been recognized, many experimental and clinical studies have been conducted. The outcomes were contributive to better understanding of cardiovascular pathophysiology. (7,15,19). It is noteworthy, that for nitric oxide (NO) or endothelium-derived relaxing factor (EDRF) discovery a Nobel Price in the last year was awarded.

BIOLOGY OF ENDOTHELIUM

Endothelial cells as the inner lining of the vessels are strategically located between circulating blood, blood cells and vascular smooth muscles. In a person with the body weight of 70 kg, the endothelium covers an area of approx. 700 m^2 and weights about 1 to 1. 5 kg. Its functional integrity is crucial for maintenance of blood flow and antithrombotic capacity due to control of essential functions like relaxation, vasoconstriction, thrombogenesis, fibrinolysis, platelet activation and inhibition. Thus, the endothelium contributes to blood pressure control, blood flow and vessel patency. Conversely, the impaired endothelial function contributes substantially to cardiovascular disorders such as atherosclerosis, hypertension, CAD, heart failure, etc., with their sequelae for the end-organs functioning (1,2,3,5,7,15, 23,24).

PHYSIOLOGY OF THE ENDOTHELIUM

Endothelium-derived Relaxing Factor

Stimulation of intact endothelial cells by various substances like neurotransmitters, hormones, agents derived from platelets and coagulation system causes release of a substance marked NO or EDRF which induces relaxation of underlying vascular smooth muscles. What is more, shear stress (forces exerting on the vessel wall during the cardiac cycles) generated by circulating blood flow induce endothelium-dependent vasodilatation. This is an important adaptive response of the vasculature during the physical activity as well. NO production is regulated with an enzyme NO synthase released constitutively as well as by shear stress and estrogens. There is a clear evidence, that vasculature is in a constant state of vasodilation due to continuous basal release of NO by the endothelium. Furthermore, endothelial cells release prostacyclin (PGI_2) in response to shear stress and hypoxia which like NO synergistically inhibits platelet aggregation.

Endothelium-derived Contraction Factors

After NO existence has been discovered, it became clear, that it must exist a contracting factor as well. Endothelium-derived contracting factors involve group of endothelin-1,2,3 (ET-1,2,3) and a family of 21-amino acid peptide prostanoids like thromboxane A_2, prostaglandin H_2 and components of renin-angiotensin system (RAS) such as angiotensin II (AT II). Cardiovascular endothelial cells produce ET-1 exclusively. An important role in the transformation and expression of ET-1 plays an endotheline-converting enzyme (ECE). Release of ET-1 is stimulated by thrombin, transforming growth factor beta, interleukin-1, epinephrine, AT II and arginin-vasopressin. ET-1 causes vasodilation in lower concentration, but marked and sustained contraction at higher concentration. In the heart, it may eventually lead to ischemia, arrhythmias or even a sudden death. What is of interest, intramyocardial vessels are more sensitive to ET-1 effect than epicardial coronary arteries. ET-1 have inhibitory factors as well. To the main four substances pertain cGMP-dependent inhibitor, cAMP-dependend inhibitor, inhibitory

factor produced by smooth muscle cells and estrogens. Additionally, the endothelium regulates the activity of the RAS due to ACE expression on the endothelial cell membrane either. This substance is identical to kinase II, which inactivates bradykinin.

ENDOTHELIUM PATHOPHYSIOLOGY – ENDOTHELIAL DYSFUNCTION

Endothelium dysfunction can be defined as an imbalance of endothelium-derived relaxing and contracting factors. It may be the cause or consequence of vascular disease and is a hallmark of known cardiovascular risk factors (17). It is essential that endothelial dysfunction precedes structural vascular alterations indicating a protective role of the functionally intact endothelium. Normally, endothelium does not stimulate migration and proliferation of vascular smooth muscle cells. But with onset of endothelial dysfunction , platelets and monocytes adhere to the vessel wall and later on, the growth factors are released not only from these cells, but also from the endothelium.

Cardiovascular Risk Factors and Endothelial Dysfunction

Aging

Aging is now recognized as an important independent risk factor for cardiovascular diseases development. The effect of aging in humans on endothelium-dependent vasodilation of coronary arteries is characterized by significantly decreased coronary blood flow response to acetylcholine (Ach). Age-related decrease in the production or responsiveness to NO, increased response to/or production of vasoconstricting factors, or increased degradation of NO respectively, are typical findings which may lead to the mentioned effects. Moreover, there is a difference between genders in the loss of flow-mediated dilation. The decline in men used to begin toward the end of fourth decade, in women this process did not start until after the early fifties. Later on, approximately at around the age of 65, endothelial dysfunction is supposed to be found in all subjects.

Vascular aging seems to be caused either by impaired release of vasoactive mediators or by an increased oxidative stress. In most studies, endothelium-dependent relaxations decrease with aging, or an increase in coronary flow induced by acetylcholine infusion lessens with age. Recent studies support the idea, that the decline in endothelium-dependent relaxation may be related to a decrease either in basal or stimulated release of NO and/or to reduced expression of the endothelial NO synthase gene. Although the plasma level of ET-1 increases with age, organs response to its release decreases, presumably due to receptors downregulation. Furthermore , functional ECE activity is heterogeneously affected with aging, which may lead to an increase in some, but not all arteries.

Hypercholesterolemia and Atherosclerosis

Hypercholesterolemia per se, i. e. without atherosclerotic vascular changes , inhibits endothelium-dependent relaxation, which is more extensive in more advanced atherosclerosis. What is more, hypercholesterolemia enhances the response to vasoconstriction agonists and attenuates endothelium-dependent relaxations in isolated vessels. Reduced activity of endothelium-dependent NO is an initiating factor in atherogenesis. The key role in that phenomenon plays LDL-cholesterol, particularly after a oxidation. The oxidized LDL-cholesterol impairs the activity of NO synthase enzyme. The consequence is, that both in hypercholesterolemia and atherosclerosis, biologically active NO is substantially reduced. It has been revealed, that endothelium-derived NO fosters the inhibition of several pathologic processes like monocyte adherence and chemotaxis, platelet adherence and aggregation and finally vascular smooth muscle proliferation. Fortunately, the endothelial dysfunction is a reversible process, which can be positively influenced by administration of NO precursor L-arginine in hypercholesterolemic individuals (1). Conversely, endothelin-1 is activated in atherosclerotic vascular disease, as well as by hyperlipidemia. As it has been stated, likely the most stimulus for the increased endothelin-1 production is LDL-cholesterol level, which increases endothelin gene expression and release. Additionally, vascular smooth muscle cells migrating into the intima during the atherosclerotic process produce endothelin-1either.

Hypertension

Hypertension is another condition when endothelial dysfunction may contribute to an increase in peripheral resistance , particularly in

small arteries, or to vascular complications of the disease in medium and large-sized conduit arteries. In most models of hypertension, this illness is associated with reduced endothelium-dependent relaxation. Endothelial dysfunction seems to be more the consequence rather than a cause of hypertension. The endothelial dysfunction in individuals with essential hypertension appears to be due to a defect in the NO synthase pathway, that is unfortunately not reversible by NO precursor L-arginin administration. Similarly the salt-induced hypertension is associated with markedly impaired endothelial NO synthase activity. A defect in the endothelium-derived NO system, possibly decreased synthesis and/or release of NO by endothelial cells, is now known to cause the abnormal response to Ach in hypertensive vessels and thus partially contributes to increased vascular resistance typical for hypertension. There have been four mechanisms responsible for it in consideration, but none of these mechanisms have been proven so far definitely (1).

Diabetes mellitus

In case of *diabetes mellitus* it has been proven, that an elevated level of glucose cause endothelial dysfunction. Mechanism hidden behind that phenomenon may involve an increased synthesis of endothelin-1 and/or impairment in NO expression pathway. Reduced production of NO does not seem to be the cause of the impaired relaxation. A particular role pertains rather to prostaglandin having a vasoconstricting effect in response to higher glucose level, which in reality overcomes the normal vasodilating effect of NO released by endothelium. Otherwise, there is a consensus, that elevated glucose plasma levels contribute to higher oxidative stress, which may lead to natural antioxidant power perturbation, i.e. may bring about a lack of defense.

Sedentary Lifestyle

A lack of exercise generally is considered as a risk factor for atherogenesis, independent on its negative effects e.g. on body weight, blood pressure and lipid status. It has been discovered, that the lack of an adequate physical activity may be associated with reduced expression of NO synthase and thereby with decreased synthesis of NO.

Estrogen deficiency

It has been proven that estrogen replacement therapy is associated with a decreased risk of cardiovascular morbidity and mortality in postmenopausal women (1). Accordingly, the male gender is considered as an independent risk factor for CAD. On one hand, estrogen modulates NO synthase activity and thus the production of NO. On the other hand, estrogen deficiency is associated with endothelial dysfunction development and increased levels of circulating endothelin-1. These clinical findings show a possible and reasonable pathway how to change our approach to the prevention from consecutive endothelial dysfunction alterations.

Smoking

The main effect of cigarettes smoking can be summarized as vasoconstriction, platelet aggregation and monocyte adhesion, which contribute undoubtedly to increased risk of atherosclerosis and other forms of cardiovascular diseases. It is supposed to be a higher turnover and desquamation of the endothelium cells with expected sequelae (1).

Stress

Stress environment, particularly in aviation, can not be omitted. It has been recognized as an important part of this profession and deleterious condition even for cardiovascular disease development as well (9,12,20). Any aviator more or less, must face with it, especially during operational missions, overseas operations etc. The simple clinical sign of activated sympathetic system is the tachycardia. It has been confirmed in current studies (13,30) that the increased heart rate (HR) is an independent risk factor or even predictor for coronary mortality(11). It can be currently summarized: firstly, tachycardia pertains to the reliable markers of increased sympathetic activity. Secondly, there is a statistically significant correlation between tachycardia and later hypertension development (12). Thirdly, tachycardia is a predictor of later CAD development. A typical response to acute or repeated stress stimulus is characterized by catecholamines release, which is regulated via hypothalamus-pituitary gland-peripheral organs pathway. Moreover, higher HR is associated with hyperglycemia and hypercholesterolemia as well

(11). It is well known, that s.c. borderline hypertension is linked with hyperdynamic circulation and is recognized as an important risk factor in some individuals. The imbalance between sympathetic and parasympathetic nerves is supposed to be a triggering mechanism. Moreover, the whole process is influenced negatively by smoking, alcohol intake, bad dietary regimens and finally with the individual ´s mood, e.g. anxiety. Sympathetic activation leads to the catecholamines excretion. The clinical response to catecholamine release leads to a remarkable increase in HR, cardiac output, blood pressure and platelet aggregation as well. Moreover, catecholamines speed up the vessel ´s wall aging process by hypertension development and tendency to thrombogenesis. Combination of higher catecholamine plasma levels and hyperinsulinemia contributes cumulatively to the vessel ´s wall damages, particularly endothelial cells and smooth muscle cells located in the media. The impact is progression of atherogenesis. Finally, catecholamines interact both with alpha and beta-receptors. Alpha-receptors activation leads to vasoconstriction with a reduction of blood flow to the organs.

The second phase of stress reaction can be characterized by a higher cortisol production. Consequently the extracellular volume, cortisol, as well as ACE excretion increases, the excretion of kinase and prostaglandines decreases. These changes cause at the end the increase in cardiac output and peripheral vessels resistance. Furthermore, with aging and associated higher responsiveness to cortisol , the duration of recovery phase becomes longer.

Endothelial Function and Oxidative Stress

The increased oxidative stress has been linked to a wide variety of degenerative processes and diseases such as atherosclerosis, stroke, ischemia and a wide variety of age-related disorders and the aging process. Sometimes is difficult to demonstrate cause and effect relationships between these diseases and antioxidant state because oxidant damage is subtle, difficult to measure, which develops over the years. In order to survive in the "unfriendly" environment created by oxygen radicals, living organisms generate a variety of water- and lipid-soluble antioxidants. As antioxidant can be marked any substance, which delays the oxidation of the substrate. They may work by preventing the generation of oxidizing species, by scavenging or by reducing free radicals. The inactivation of free radicals also known as "chain breaking" is particularly important in lipid structures that contain easily oxidizable compounds like LDL-cholesterol and unsaturated fatty acids. There is a battery of endogenously synthesized antioxidant enzymes such as superoxide dismuthase enzyme (SOD), catalase, glutathione peroxidase, which intercept and inactivate these reactive species. Problem arise, when the amount of oxidative stress overwhelms the capacity of antioxidants. Both endothelial and vascular smooth muscle cells are capable of producing reactive oxygen species from variety of enzymatic sources. In disease state, e.g. hypertension, production of these reactive oxygen metabolites can increase substantially. Higher production of superoxide anion may lead to decreases in ambient levels of NO due to facile radical reaction more rapidly than the excretion of superoxide anion caused by SOD. This phenomenon alters endothelial regulation of vasomotion in different diseases. The major source of vascular superoxide ion and hydrogen peroxide is a membrane-bound, reduced nicotinamide-adenine-dinucleotide (NADH)-dependent oxidase. The activity of this enzyme is regulated by AT II and is elevated after a prolonged nitroglycerin administration as well. Alterations of vascular oxidant state caused by AT II may contribute to vascular pathology and provide a link between hypertension and atherosclerosis.

Vasculoprotective and Cardioprotective Mechanisms of ACE Inhibition: Balance between AT II and NO

The process of vascular remodeling – *the ability of vasculature to modify its geometry in accordance with conditions of its microenvironment* – represents an important pathophysiologic process common to vascular disorders. A growing body of evidence indicates, that locally generated vasoactive substances like AT II and NO are those determinants of the natural history of vascular diseases. AT II may also promote chronic hypertension by modulating the vascular redox state and promoting the catabolism of endothelium-derived NO. Thus, the ACE inhibition may have reasonably a profound effect on ventricular and vascular structure and

have particular efficacy in preventing the cardiovascular morbidity and mortality.

Role of Angiotensin II

Vascular remodeling involves a cascade of alterations. These alterations in vessel structure are now considered as essential determinants of vascular resistance and hypertension pathogenesis. There are several forms of remodeling, involving medial layer hypertrophy, decreased vessel and/or lumen diameter, expansion and/or alteration of the extracellular matrix and vessel rarefaction (microvessel occlusion). Final stages are then vascular hypertrophy and fibrosis within the structure of conduit and mocrocirculation, resulting from vascular remodeling. The balance between mechanisms governing vascular tone, i. e., an interplay between vasoconstrictors and vasodilators modulates the vessel resistance (6). In the course of hypertension the homeostatic balance becomes perturbed, i.e. the influence of vasoconstrictors as AT II, endothelin-1, thromboxane A_2 etc., predominates over the vasodilation caused by NO. Moreover, other vasoactive substances are now recognized as factors able to modulate the critical cellular processes involved in vascular remodeling and lesion formation (6). Except of these effects on cellular vascularity, AT II may also mediate remodeling and lesion formation by altering of extracellular matrix composition and under the influence of other substances (6). Moreover, the migration of endothelial and smooth muscle cells can be modulated by AT II as well. Similar vasoconstrictive effects have been described in other substances like norepinephrine.

Role of NO

Endogenous vasodilator like NO or natriuretic peptides appear to have a countervailing influence to AT II. Vasodilators generally inhibit vascular smooth muscle cell growth. They also may promote a decrease in vascular smooth muscle cellularity by inducing the programmed death. Taken together, one may speculate, that decreased NO generation is associated with shrinkage remodeling, whereas increased NO generation is associated with enlargement remodeling. Similarly, an increase in oxidative stress will mitigate the vasodilatory bioactivity of NO. The imbalance between NO and reactive oxygen species, characterizing the endothelial dysfunction development, may be an important pathogenic mechanism in hypertension, that determines the level of blood pressure, promotes alterations in vessel structure and contributes to hypertension complications such as CAD.

Role of ACE Inhibition : Perspectives in Prevention of Endothelial Dysfunction

To the degree that vascular disease is characterized by an imbalance between a relative increase in AT II and a relative deficit of NO bioactivity, it is postulated that ACE inhibition may effectively restore the appropriate homeostatic balance between these vasoactive systems. This hypothesis has been now tested in clinical trials (18,23). There is a compelling evidence indicating that long-term administration of ACE inhibitors reverses endothelial dysfunction in patients with either hypertension or atherosclerotic vascular disease. They appear to have particular efficacy in reversing vascular remodeling process and thus prevent from the eventual hypertension development as well as in patients with existing essential hypertension (23,30). This observation supports the hypothesis, that antihypertensive agents that reduce blood pressure and reverse the remodeling process may substantially change the natural history and the course of the disease. Beneficial effects of ACE inhibitors has been proven in patients with left ventricular dysfunction due to hypertrophy (2,18,21,23). They reduced the incidence of recurrent myocardial infarctions as well. This fact indicates, that ACE inhibitors may alter the natural history of CAD, possibly via direct effects on coronary vascular function and structure. It has been documented, that ACE inhibitors probably reduce the myocardial oxygen consumption in association with an increase in NO generation either. These findings are consistent with previous studies demonstrating that NO has a direct effect on muscle oxidative metabolism. It raise the possibility, that ACE inhibition may prevent myocardial ischemia by optimizing the balance between myocardial oxygen supply and demand. Furthermore, there are clinical studies under way that will directly test the hypothesis that chronic administration of ACE inhibitors in normotensive individuals with CAD will prevent ischemic events (3).

POTENTIAL INTERVENTIONS IN ENDOTHELIAL DYSFUNCTION

1) Nonpharmacological Interventions

With the knowledge of endothelium functions some interventions targeted exclusively at the endothelium monolayer may be developed in the future in order to improve endothelial dysfunction sequelae.

Low-cholesterol Diet

It has been found out, that dietary treatment restored impaired endothelium-dependent vascular relaxation (8). Particularly high intake of fish oil appeared to result in a low incidence of CAD. Fatty acids in marine fish oil differ chemically from those of land animals and vegetable oil – they contain greater percentage of polyunsaturated fatty acids, which are less vulnerable to oxidation. Eicosapentaenoic and docosahexaenoic acids in marine lipids can substitute to arachidonic acid. Like arachidonic acid, they can be converted into an active form of prostacyclin (a vasodilator and platelet aggregation inhibitor). Unlike arachidonic acid, they are converted into an inactive form of thromboxane A_2 (vasoconstrictor and platelet agonist). Therefore, these omega-3 fatty acids shift the balance in the arachidonic acid cascade to the side of the vasodilator/platelet antagonist prostacyclin.

Exercise

Beneficial effect of regular physical activity on endothelial dysfunction is now recognized due to increased endothelium-derived NO release via the shear stress effects.

Smoking cessation

The improvement in vascular function that follow cigarette smoking cessation particularly reverses the adverse effect of smoking on vasculature. Moreover, the lipid profile also benefits from smoking cessation due to HDL- cholesterol and apolipoprotein A-1 increase , whereas triglycerides decrease.

Antioxidant supplements

Because oxidation of LDL-cholesterol contributes to endothelial dysfunction, researchers have reasoned, that a diet rich in antioxidants may be protective, but results of clinical studies have not consistently shown a benefit of administering substances like vitamins E, C, beta-carotene, minerals as selenium and coenzymes, e.g. Q10 or non-vitamin antioxidants as flavonoids.

L-arginine supplementation

With the recognition of NO function, interest has begun to center on L-arginine, the precursor of NO. It has been hypothesized, that increasing availability of L-arginine might enhance synthesis of NO and thereby promote vasodilation, but the evidence for that hypothesis has been still missing.

2) Pharmacological Interventions

There are several categories of drugs used to treat cardiovascular diseases that have proven its primary medical effect to ameliorate or even improve an impaired endothelial cells relaxing effect.

Lipid-lowering agents

Particularly s.c. statins, i.e. HMG-CoA reductase inhibitors, improve vasodilative response in a long-term treatment. The effect was significantly greater in combined therapy with antioxidant substances that have been added to the regimen (1,3).

ACE inhibitors

AT II as a potent endothelium-derived contracting factor is produced by the action of ACE from angiotensin I. It is normally balanced by the effects of NO and prostacyclin. When the endothelium is damaged or dysfunctional, however, the countervailing effects of these endothelial vasodilators are lessened. Improvement of endothelial dysfunction with antihypertensive agents, particularly those with long duration of action like trandolapril, ramipril, perindopril or quinapril as demonstrated in TREND Study(18), seems to be reasonable and thus applicable.

Calcium-channel blockers

Hypertension treatment with a new generation of dihydropyridine calcium antagonists e.g. amlodipin, has inhibited to a partial degree atherogenesis in humans, particularly development of new lesions. Unfortunately, there

has been not yet the evidence, that they modify existing ones (1).

Estrogen replacement

The beneficial effect of estrogens to enhance endothelial vasodilative function may be due to an antioxidant effect or to an estrogen-induced enhancement of NO synthase expression.

CLINICAL SEQUELAE OF ENDOTHELIAL DYSFUNCTION FOUND IN CZECH MILITARY CREWMEMBERS.

Based on what has been said so far, the main task should have been to preserve an intact or to improve an impaired endothelial integrity and function. It is more important from a preventive point of view, when we take into an account that endothelial dysfunction occurs prior to irreversible structural changes. Reasonable and appropriate therapy should have been initiated more earlier particularly in individuals with hypertension, familial hypercholesterolemia and hyperglycemia. Corrections or preventive countermeasures to influence the endothelial dysfunction with agents targeting the endothelium, should have been applied as soon as possible particularly in flying personnel at higher risk profile (3,29). It is the only way how to improve the clinical outcomes and prospects in these patients not only becoming older, but also threatened by above mentioned illnesses. Keeping this all in mind, we made an analysis among the group of 21 Czech military aviators, who were treated primarily for hypertension within the 5 years period (1994 – 1998).

DESIGN AND THE OUTCOMES OF THE STUDY

Aviators were sorted out in terms of age, rank, flying class, aircraft to be flown, other coexisting disorders, therapy strategies, onset and duration of medication. Special attention was paid to presence of other risk factors and bad life style habits, individual compliance and cooperation during crewmembers regular actions and follow-up. The mean age of involved aviators was 46 years (31 - 59). Two thirds were higher ranking officers, one third lower ranking ones. Mean duration of medication lasted 4,62 years (0,2 – 13). Only hypertension was found in 14,30%, another two underlying diagnoses in 66,70% and in 19% more than two chronic illnesses were found. Two combination therapy strategy was used in 57,20%, monotherapy in 42,80% was administered. Within the study the therapy selection was changed in 53,40%. We stopped using nonselective betablockers and dihydropyridine Ca antagonists like nifedipin at all. We substituted them with betaxolol and calcium channel blockers with longer duration of action as verapamil and amlodipin and ACE inhibitors like trandolapril and ramipril respectively. Diuretics have remained in the treatment of hypertension as a " golden standard ". Furthermore, 4 crewmembers were treated for hypercholesterolemia with lovastatin, pravastatin and fenofibrates, 2 with allopurinol because of hyperuricemia. We did not observe any unwanted side effects during the therapy. When searching for the presence of other risk factors, we found out cigarettes smoking in 23,80%, hyperlipidemia in 81,00%, hyperuricemia in 38,10% and overweight in 85,70% (BMI>25). Positive medical history for CAD was found in 47,10%. We succeeded in good control of hypertension pharmacologically, but we failed in influencing and elimination of present risk factors and bad life style habits. No wonder, that within the 5 years period 3 cases of myocardial infarction occurred. It should be stressed, that all 3 aviators had hyperlipidemia, two of them were recent stop-smokers, one was treated for peripheral vessel disease of atherosclerotic origin in the past 4 years. Until the CAD event, they were treated with propranolol and nifedipin.

DISCUSSION AND AEROMEDICAL CONSIDERATIONS

Coronary artery disease, which continues to be a leading cause of morbidity and mortality, is one presentation in a continuum of events that may lead to its end-stage, i.e. clinical manifestation with its sequelae from an aeromedical point of view as documented by many studies (3,14,20,24,26,29). Common to the pathogenesis of most cardiovascular diseases are the conditions often called risk factors. That cause pathologic changes and dysfunction both in the heart and blood vessels, and lead to function impairment more earlier prior to clinical manifestation (23). In the last decade, our understanding of the pathogenesis of cardiovascular diseases has increased. One important result of this is recognition of the central role played in

circulatory homeostasis by the cells that line the vascular system – the endothelium. Endothelium, generally considered, have many critically important functions. These include synthesis and release of biologically active substances that have either local and distant functions within the blood vessel wall or at its surface. The pathophysiological changes that occur in endothelial cell structure and function also characterize many of the pathomechanisms responsible for development and progression of atherosclerosis and CAD. We currently know, that many of s.c. risk factors for CAD can be modified by non-pharmacological or pharmacological interventions. As shown above, endothelial dysfunction lies „ at the heart „ of a wide spectrum of cardiovascular diseases. In contrast, as it has been shown in our group of hypertensive airmen, those who ended-up their professional career due to CAD development were treated mostly with remedies having efficient effect only on blood pressure level, but hardly ever beneficial effect on endothelial function. Similarly individuals with hyperlipidemias, despite the treatment with statins, were subjected probably to an inappropriate regimens and an ineffective pharmacological control of known metabolic disorders. Other changeable risk factors like smoking and lack of physical activity are both long-lasting aeromedical problems we have been facing with for a long time. In fact, it still remains a common challenge not only for commanders, flight surgeons, but especially for aviators - to change such an undesirable trend. There is a need to change their own minds i.e. to be more involved in personal attitude toward the sound life style in order to be fit to flying. Higher intake of fish oils is another sophisticated approach how to contribute to endothelium cells protection as well as to reduction in higher consumption of sugary food preventing from deteriorating oxidant stress sequelae. On the other hand the supplementation with estrogens, L-arginin, seems to be reasonable but questionable because of the safe administration. Further clinical trials will be needed to prove their beneficial effects in prevention of endothelial dysfunction development. Moreover, it should be taken into an account expected problems with the waiverability of these substances. When we turn back to the question at the headline, we can state, that aging or process of aging has been grasped more or less as a biological term. It is now clear, that the process of aging encompasses many simultaneously undergoing changes on cellular and biochemical level, characterized by a decrease of relaxing substances and an increase of contracting ones, resulting in their dysbalance. Involved in that process are enzymes, hormones, metabolic products, toxins, mechanical stress, nutritious factors, endocrine substances, exogenous factors, stress, as well as an emotional profile . With the presence of particular s. c. risk factors as stated, the result is endothelial dysfunction as an initial stage, later on the end-organ damages occur, obviously earlier then expected with a deleterious impact on the health status. These facts are now more understandable and this knowledge gives us more chances to slow down conditions indisputably linked with aging. This is our professional mission to move on and try to shift forward the care our aviators deserve.

CONCLUSIONS

Based on what has been expressed so far, we can formulate possible pathways in order to reverse undesirable impacts of aging particularly on cardiovascular system. The reason is clear – cardiovascular diseases represent still the most frequent reason for disqualification from flying status.

Changeable factors:

Hypertension

When selecting a convenient remedy, it should be preferred the use of ACE inhibitors and Calcium channel blockers with long and ultra-long duration of action as the first step therapy if not contraindicated

Hyperlipidemias

The reasonable lipid-lowering agents, besides the strict dietary regimens, should be mainly statins administered, followed by a regular specialist supervision

Smoking

To resolve that problem requires to start with programmes like preference of non-smokers among the candidates or enhance educational programmes among smokers in order to persuade them about the advantage of quitting smoking particularly for health status and career prolongation.

Sedentary life style

Sufficient and regular physical activity should be a part of flight training during the whole career along with the weight control.

Higher intake of sugary food and alcohol

Restriction of both has a proven beneficial effect in preventing from endothelial dysfunction development via inhibition of vascular endothelial growth factor effects and ameliorates oxidative stress sequelae not only for the endothelial cells as well.

Unchangeable factors

Advancing age
Positive medical history for C-V diseases

Unresolved factors

Hyperuricemia
Hyperinsulinemia
L-arginin, estrogen administration
Behavioral type
Hyperdynamic circulation
Stress

Disclaimer: The opinions and recommendations contained herein are the personal views of the author and are not to be construed as reflecting the views of Czech Air Force and Ministry of Defense. Moreover, the author offer this essentially as a discussion paper to sound out the views of interested and informed colleagues rather than as a finished viewpoint.

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ÉTUDE DES FACTEURS DE RISQUE CARDIOVASCULAIRE ET DES CHANGEMENTS DE L'ACUITÉ VISUELLE DUS AU VIEILLISSEMENT CHEZ LES PILOTES DE L'ARMÉE DE L'AIR PORTUGAISE

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INTRODUCTION - Ce travail est un essai pour trouver des rapports entre le veillissement des pilotes et quelques paramètres habituellement recueillis aux examens annuels d'aptitude médicale realisés au Centre de Médecine Aéronautique de l´Armée de l´Air Portugaise (FAP)

MATERIEL ET METHODES – Du fichier du Centre les auteurs ont retiré, 78 procès aéromédicales, d'une façon aléatoire.

Les données utilisées dans ce travail correspondent aux évaluations faites aux pilotes en plusieurs étapes: en tant que candidats, après 5, 10, 15, 20 et 25 années de service. Les auteurs ont recueilli des informations concernant les habitudes tabagiques et alcooliques, le poids, l'acuité visuelle, la pression arterielle et les valeurs du cholestérol et de la glucose dans le sang.

Les pilotes étaient tous du sexe masculin, avec des âges comprises entre les 16 et les28 ans (moyenne – 19,6 ans) à la prémière observation et entre les 40 et les 58 ans (moyenne 44 ans) à la dérnière observation. On peut observer la distribution sur le Tableau 1 :

1ère observ.		6ème observ.	
Age	Numéro de pilotes	Age	Numéro de pilotes
16	1	40	1
17	4	41	6
18	8	42	4
19	20	43	12
20	22	44	15
21	4	45	12
22	2	46	5
23	1	47	3
24		48	2
25	1	49	1
26		50	
27		51	
28	1	52	1

De la totalité des procès on a été exclus 14, faute d' information de six du total des observations demandées par les auteurs ou parce que la différence d'âge entre la première et la dernière observation était inférieur ou égal à vingt ans.

RESULTATS – On examine, alors, les résultats des 64 procès aéromédicales qui ont été étudiés par les auteurs:

1 – HABITUDES TABAGIQUES ET ALCOOLIQUES:

1.1.- TABAC – la population étudiée comprend 29 non fumeurs et 35 fumeurs. De ceux-ci, seulement 3 ont abandonné la consommation de tabac pendant la période considérée.

1.2. – ALCOOL – on a trouvé 34 avec des habitudes alcooliques, pas quantifiées. 25 pilotes n'avaient pas d'habitudes alcooliques et, il n'y avait pas de référence concernant les autres 5.

2. – POIDS – dans la première observation, comme candidats, le poids minimum enregistré a été de 52 Kg et le maximum de 94 Kg. Dans la dernière observation, la sixième, les valeurs trouvées ont été de 60 Kg et 101 Kg, respectivement. Du total des pilotes, la variation mineure observée a été de –2Kg et la majeure de +35,5 Kg ; la variation moyenne générale étant d'une augmentation de poids égal à 12,73 Kg, soit 19,6%. Seulement 9 pilotes ont présenté dans la dernière observation une augmentation de poids égale ou supérieure à 30% à leur poids en tant que candidats. De l'analyse des données on constate une augmentation progressive des moyennes de poids tous les 5 ans, comme l'on peut observer sur le Tableau 2 :

Moyenne à l'entrée	66 Kg
Moyenne après 5 ans	69 Kg
Moyenne après 10 ans	71 Kg
Moyenne après 15 ans	74 Kg
Moyenne après 20 ans	77 Kg
Moyenne après 25 ans	79 Kg
Moyenne de la différence 0-25	**12,7 Kg**

Paper presented at the RTO HFM Symposium on "Operational Issues of Aging Crewmembers", held in Toulon, France, 11-14 October 1999, and published in RTO MP-33.

3 – ACUITÉ VISUELLE – il est demandé à tous les candidats pilotes de la FAP une acuité visuelle de 10/10 dans les deux yeux. Il n'est donc pas de relever que 63/64 des premières observations enregistrées sur l'échantillon présente de tellles valeurs. Le seul cas différent est celui d'un pilote avec 2000 heures de vol. L'explication de ce fait est la suivante : la date de la première observation enregistrée, 1970, est antérieure de quatre ans à la création du Centre. Dans la sixième observation, 39/64 avaient une acuité visuelle de 10/10 dans les deux yeux, 7/64 présentaient 10/10 dans un oeil, et seulement 18 avaient une acuité inférieure à 10/10 bilatéralement.

4 – PRESSION ARTERIELLE – seulement quatre des pilotes évalués ont présenté, le long des temps, des critères d'hypertension arterielle. Ils ont été médicamentés, et depuis ces dates ils ont présenté des valeurs normales, ayant maintenue leur aptitude pour le vol. À 25 ans, 3 d'entre le total, présentaient des valeurs de pression diastolique égaux à 90 mmHg, avec des valeurs normales de la pression sistolique. Maintenus sous surveillance, non médicamentés et toujours aptes pour le vol.

5 – GLYCEMIE – les valeurs de référence de notre laboratoire vont de 3,3 mmol/L à 6,6 mmol/L. Dans la première observation 7 candidats pilotes présentaient des valeurs supérieures au maximum de la référence. Ces valeurs étaient dûes à l'interruption du jeûne, puisqu' aucun d'eux n'a présenté depuis des valeurs élevées. Sur le Tableau 3 on présente la variation des glycémies le long des six observations :

Elevées à l'entrée	7
Elevées après 5 ans	0
Elevées après 10 ans	1
Elevées après 15 ans	5
Elevées après 20 ans	2
Elevées après 25 ans	1
= ou > 2 valeurs élevées	2

Bien qu'on trouve des valeurs élevées en différentes obervations, aucun des pilotes ne présente de la Diabète Mellitus.

6 – CHOLESTEROLEMIE – pour ce paramètre nous présentons les valeurs de référence de notre laboratoire, sur le Tableau 4:

	mmol / L
Risque élevé	> 6.1
Risque modéré	5.2 – 6.1
Bas risque	< 5.2

Il n'y a pas de valeurs dans les deux premières observations car la détermination de la valeur de la cholestérolemie est de récente introduction (années 80) relativement aux examens d'aptitude médicale du personnel de vol. Sur le Tableau 5 nous vous présentons les données concernant seulement la variation de la cholestérolemie, en ne considérant élevées que les valeurs supérieures à 6,1 mmol/L :

Élevées à l'entrée	0
Elevées après 5 ans	0
Elevées après 10 ans	14
Elevées après 15 ans	4
Elevées après 20 ans	32
Elevées après 25 ans	32
= ou > 2 valeurs élevées	29

On peut remarquer que les valeurs élevées, qui correspondent à la moitié de la population observée (32/64) apparaissent en pilotes âgés de 35 à 47 ans à l'époque de l'avant-dernière observation et de 40 à 52 ans à la dernière.

7 – PATHOLOGIE ASSOCIEE - simultanément, les auteurs ont considéré de tout intérêt faire l'analyse de la pathologie dont on fait référence dans les procès aeromédicales, même si elle ne présente aucun rapport direct avec les parametres étudiés, mais que nous croyons approprié quand il s'agit d'évaluer le procès de vieillissement (Tableau 6) :

Alts. de la repolarisation de l'ECG	7	
Rachialgies	5	
Hernie Discale Lombaire	3	2 chirurgies
Varices des membres inférieurs	2	
Kyste dermoïde sacroccocygien	2	
Lithiase urinaire	2	
Sinusite	1	
Spondilarthrite ankylosante	1	
Wolf-Parkinson-White	1	
Hématome intra-cérébral	1	
Méningiome	1	
Ulcère gastro-duodénal	1	chirurgie
Hypertension oculaire	1	

DISCUSSION ET CONCLUSIONS –

1 – Quant aux habitudes tabagiques, l'existence de 54,6% de fumeurs dans cet étude n'est pas surprenante pour les auteurs, bien que nous n'ayons pas de données concrètes par rapport à la pourcentage d'hommes fumeurs dans la population portugaise du même âge. Cependant, il faut remarquer que dans la nouvelle génération de pilotes, et pareilllement à la tendance générale du pays, le numéro de fumeurs est en train de diminuer.

Du total (64) seulement trois pilotes ont abandonné le tabac (8,5%), ce qui nous paraît très peu. Ce result devant obliger à un plus grand engagement en campagnes d'éclaircissement et programmmes d'abstinence médicalement assistés. On sait que la consommation de 20 cigarettes / jour, accroît environ 70% le taux de mortalité et, chez les hommes, augmente 3 à 5 fois le risque de cardiopathie ischemique. Ên tout cas, on sait que, après un an d'abstinence tabagique, les risques de cardiopathie sont pareils aux des non fumeurs.

2 – On verifie que chez 34 pilotes (53,1%) il y a des habitudes alcooliques permanents, pas quantifiés. Les dernières données disponibles indiquent que le Portugal est le pays européen avec la plus grande consommation de boissons alcooliques; la valeur trouvée chez les pilotes est, heureusement, au dessous des valeurs espérées. Il faut souligner que ces informations, sur les habitudes alcooliques, nous sont transmises volontairement par les pilotes.

3 – Comme les valeurs de poids à l'entrée sont près du poids idéal, et la moyenne de la différence après 25 ans a été de 12,7 Kg (un surcroît de 19,6%), nous pouvons conclure que l'augmentation de poids a été relevant. On sait que la morbilité et la mortalité dûes à la cardiopathie ischémique sont plus grands et liés à un surcroît de poids au dessus de 30%. Dans notre étude 9 pilotes (14,06%) présentent ces caractéristiques, ayant donc un profil cardiovasculaire défavorable.

L'augmentation de poids, progressive et excessive se verifie aussi dans la population portugaise en général, et peut être compris, au cas de la FAP, par le régime diététique et par la sédentarité progressive.

4 – Plusieurs études indiquent que la hypertension arterielle apparaît habituellement en personnes plus âgées que la population de cet étude ; pas surprenant donc, que seulement 4 pilotes aient des valeurs de tension élevées, et soient indiqués pour inicier une thérapeutique. Outre les pilotes indiqués, il n'y a que trois qui presentaient des valeurs de pression diatolique de 90 mmHg, alors sans indication thérapeutique. On sait que quelques facteurs environnementaux, comme l'ingestion de sel, l' alcool, l' obésité et le type d' occupation sont responsables par le développement de l' hypertension. Puisque quelques-uns de ces facteurs sont présents chez la population portugaises e définitivement dans les Forces Armées, la réalisation d' un étude complémentaire serait intéressante.

5 – Le Diabète Mellitus est sûrement un facteur de risque cardiovasculaire. Les diabétiques présentent des taux de mortalité par cardiopathie ischémique 3 à 5 fois plus élevés que ceux de la population en général. À l' occasion de la selection du personnel de vol, le diagnostic de Diabète Mellitus insulino-dépendent est toujours cause d' inaptitude. De l'autre côté le Diabète Mellitus non insulino-dépendent apparaît surtout chez les plus âgés, en étant possible qu'il soit absent dans notre échantillon. Les valeurs élevées sur le Tableau 2 correspondent aux valeurs de hyperglicémies et pas à l'existence de Diabète.

6 – Le régime alimentaire portugais est extremement favorable à la manifestation de niveaux de cholésterolemie élevés; pas surprenants les résultats de cet étude qui seraient éventuellement plus hauts si, à l'époque des deux premières évaluations, ces valeurs fussent déterminés.

Ce Centre a fait des efforts pour changer les régimes dans les Bases Aériennes qui, jusqu'à présent se sont montrés vains.

En tout cas, aux stages d'entraînement physiologique et aux briefings des Officiers Médecins Aéronautiques dans les Esquadrons de Vol, quelques notions de régimes équilibrés et d' habitudes de vie saine sont données.

7 – On n'a pas vérifié d'altérations significatives de l'acuité visuelle, ce qui est normale dans une population relativement jeune et sélectionée, comme celle qui constitue notre échantillon.

8 – En ce qui concerne la pathologie associée, il ne semble correct d'établir n'importe quel type de rapport avec le vieillissement, à l'exception des 7 cas d'altérations de l'ECG, apparemment sans valeur pathologique.

9 – Bref : celui-ci est le premier étude que nous faisons sur ce sujet. Après tout cela on a l'aiguillon pour continuer à ramasser et travailler les données, pour qu'on puisse définir d'autres formes de combattre les facteurs de risque cardiovasculaire, en augmentant les niveaux de sûreté de vol.

OCULAR PROBLEMS OF THE AGING MILITARY AVIATOR

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INTRODUCTION:

Approximately 20% of all the USAF aviators are now over the age of 40. Over 60% of the U.S. civilian airline pilots are over the age of 40. Because of the age 60 rule, these pilots must retire when they reach 60 years of age.

We decided to look at what are the ocular/visual problems that brought our senior USAF aviators to the Consultation Service at the USAF School of Aerospace Medicine at Brooks AFB, Texas. The Consultation Service evaluates all USAF aviators who have a medical problem that threatens their flight status. Following a through medical workup, our staff makes a recommendation to the USAF Surgeon Generals Office. This might be grounding, further treatment, a waiver to return to flight status or change in flight status. (1)

METHODS:

The medical records of all USAF aircrew over age 45 were examined. They were seen in the Consultation Service from 1 Jan 86 through 19 Dec 95, a 10-year study. These individuals were sent to us to be evaluated for their fitness to return to the cockpit. The frequency with which these ocular conditions were seen was noted, as were the causes for grounding of these individuals. One could ask an important question here: Have advancements in medicine and science since 1959, when The Age 60 (2) rule came into being, had any effect on these ocular conditions seen in the older aviator and on his flight status?

FINDINGS:

The total number of new cases over age 45 seen during this 10-year period was 149 aircrew. Their ages ranged from 46 to 71 years, with the average age being 50.1 years. A few of the older subjects were retired military aviators now working as civilian flying instructors for the U.S. Amry. Table 1 shows the breakout of the aircrew positions.

TABLE 1. BREAKOUT OF AIRCREW POSITIONS

Pilots	100
Navigators	33
Flight Surgeons	12
Loadmasters	2
Gunner	1
Flight Engineer	1
TOTAL	149

In table 2 we see the variety of ocular conditions that were potentially gounding and therefore these cases were sent to the Consultation Service for disposition.

TABLE 2. DIAGNOSES AND FREQUENCY

Presbyopia	149*
Glaucoma/Intraocular hypertension	41
Aphakia w/intraocular lens or contact lens	35
Stereo/motility problems	19
Keratoconus or excessive refractive error	7
Retinal detachment/surgery	9
Central serous retinopathy/surgery	9
Retinal/lattice degeneration	5
Cataracts	4
Color vision defects	3
Uveitis iritis	3
Optic neuritis/ischemic neuropathy	3
Ocular trauma/angle recession	3
Branch retinal vein occlusion	2
Miscellaneous diagnoses on Table 3	11
Total diagnoses exclusive of presbyopia	154

*All had presbyopia

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The Miscellaneous diagnoses are shown in Table 3.

TABLE 3. MISCELLANEOUS DIAGNOSES

Acephalgic migraine	1
Corneal dystrophy (map dot)	1
Adult-onset Best disease	1
Nutritional amblyopia (RPW)	1
Fuch's heterochromic iridocyclitis	1
Central areolar choroidal dystrophy	1
Ocular floaters	1
Ocular histoplasmosis	1
Trabeculectomy w/mitomycin C	1
Herpes simplex with corneal erosions	1
Superior oblique myokymia w/oscillopsia	1
TOTAL	11

Of the 149 subjects seen, 30 were disqualified for flying duties. This is 20% of the total. However, only 12 (8%) were disqualified for ophthalmic diagnoses, whereas 18 (12%) were disqualified for other medical conditions, predominantly cardiovascular. Therefore, these disqualifications were 40% for ocular reasons and 60% for other medical conditions. Overall, 80% of these over-age-45 aircrew were retained on flight status and only 20% were disqualified. The 12 (8%) disqualifying ophthalmic diagnoses are shown in Table 4.

TABLE 4. DISQUALIFYING DIAGNOSES

Cataract	1
Traumatic cataract	1
Glaucoma/miotic use	1
Glaucoma with visual field defects	1
Pigmentary glaucoma with visual field defects	1
Trauma with VI nerve paresis	1
Superior oblique myokymia	1
Choroidal dystrophy	1
Central serous retinopathy	1
Retinal detachment with decreased visual acuity	1
Anterior ischemic neuropathy	1
Herpetic keratitis with corneal erosions	1
TOTAL	12

DISCUSSION: Under present FAA regulations, the longest flying career one can expect is approximately 35 years. The last 15 years (from age 45 to age 60) should be the most productive for an aviator. New aircraft and high-tech cockpits have not decreased the importance of the visual sense in flying. In fact, vision now is even more important, since there has been an increased load on near vision (cockpit vision) just at the age when that function begins to gradually decrease in its capabilities. Our survey showed that none of the subjects could escape presbyopia. All 149 subjects needed a spectacle correction to pass the near vision test at 14 inches; however, we are aware that a substantial number of these individuals can get by in the cockpit without spectacle help, at least for a few years. But by age 50, no one can do the job in the cockpit without a visual aid. Even though this is a universal problem, fortunately one can correct it 100% of the time. Old and new optical technology has given us reading glasses, bifocals, trifocals, double segs, newer progressive lenses, contact lenses, and now every refractive surgery. (Fig 1)

Excluding presbyopia, in descending order of occurrence, (See Table 2) the next six diagnoses represented 78% of the conditions potentially grounding these aviators who were seen in our branch. The conditions were glaucoma and intraocular hypertension (27%); aphakia with intraocular lens or contact lens correction (22%); stereopsis and motility problems (12.%); keratoconus and excessive refractive errors (6%); retinal detachment with and without surgery (6.%); and central serous retinopathy with and without surgery (5%).

When The Age 60 rule came into being and one of us (TJT) began his career caring for AF aviators, back then a diagnosis of glaucoma was a reason for commencing drug treatment of the disease. This was usually with miotic drugs and this meant that one could be assured of being grounded for this condition. However, work done since then in the Ophthalmology Branch at USAFSAM allowed other drugs to be used in USAF aviators and, a Glaucoma/Intraocular Hypertension Surveillance Only Program was initiated. The sum total of all this was that what was almost a sure grounding in 1959 is now grounding in less than 10%; over 90% of our glaucoma/ocular hypertensive cases are kept on full flight status throughout their flying careers. In the Surveillance Only part of the program no drug therapy is used but the flight surgeon must monitor the intraocular pressure at three months intervals. At six months a visual field is done along with an evaluation of the optic nerve. If the aviator has a diagnosis of glaucoma he/she is placed on drug therapy at once. Presently the USAF protocol allows epinephrine derivatives, and beta blockers as the only drugs used to treat glaucoma in the aviator. This is so because these two drug groups do not alter the aviator's visual capabilities. (3) Ninety-two percent of these senior aviators with glaucoma/

intraocular hypertension were returned to full flight status.

The next most frequently seen affliction in senior aivators was cataracts (22%). Once again, in 1959 a diagnosis of cataract was the death-knell of an aviation career. First, by the use of contact lenses (first hard lenses and then soft) and now, with the advent of intraocular lens replacement for the natural lens, almost every aviator with cataracts can have surgery and be returned to full flight status. (4) In 1974, we returned the first aphakic aviator to flying using a contact lens to correct the aphakia, and in 1979, the first USAF aviator with an intraocular lens was returned to flying. Prior to this (in 1978) we had placed intraocular lenses in a dozen primates. After a period of healing they were subjected to up to +12 Gz. None of these lenses dislocated. We have found this to be true in following our aviators, in 20 years, only one subject dislocated his lens but this was in a secondary implantation and accidental, not during the performance of his flying duties. We presently have 65 USAF aviators (80 eyes) with intraocular lenses, 15 of them have binocular IOLs. Almost all of them (97%) have attained 20/20 vision. They fly all types of USAF aircraft from F-15 and F-16 to C-130s. Even one astronaut has flown in space with bilateral intraocular lenses in place. Only 2 of 35 of the senior aviators in this study were grounded. Ninety-four percent being returned to full flight status.

Twelve percent of our subjects had ocular motility/stereopsis problems. We discovered, that in the early 1970s, that many of the individuals who had failed stereopsis, but had "straight"-appearing eyes, had a newly discovered condition called microtropia. (5) Most of these microtropes were found to have excellent flying records and were retained on full flight status. Over 220 such individuals now have been seen in the Consultation Service since we discovered this condition in aviators. Two of the 19 motility cases in this study were grounded; thus 90% were retained on flight status.

Five percent of the cases seen had keratoconus or excessive refractive errors. One hundred percent of these were correctable by advances in optical and contact lens science and technology and returned to full flight status. This was not always so. Back in 1959, if a keratoconus case could not be corrected by spectacle lenses, and it usually could not, a military aviator's career was ended unless had a successful corneal transplant. With the advent of hard contact lenses, nearly all of our keratoconus cases could be returned to flying. (6) We now have over 60 keratoconus cases that are being followed at our institution, most wearing hard contact lenses to correct their corneal condition. In the history of our branch only one keratoconus case had corneal transplant surgery and unfortunately the surgery proved not to be successful.

Six percent of the cases reviewed were retinal detachments. Most had some form of surgery, from laser retinopexy to detachment surgery with full encircling bands. In 1959, probably none of these cases could have been rehabilitated completely. Only one of our nine cases failed to return to flight status, the other eight had successful retinal reattachments and, with optical correction (89%), were able to be returned to full flight status.

The 11% disqualification rate for retinal detachments in senior USAF aviators is the same rate we found in a previous study done in our branch looking at all the aviators evaluated for retinal detachments. (7) The effects of aviation duties especially G-forces always needs to be considered in these detachment cases. To date none of the cases in this study have re-detached. In the previous study encompassing 1967 through 1986 one case re-detached. From our experience one can say that a successfully surgically attached retina most likely will not re-detach and it is safe to return such individuals to full flight duties. (8) Obviously, after having undergone a complete and through ophthalmologic evaluation such as used in our branch, along with periodic follow-up with dilated ophthalmologic examinations.

The final one of these six diagnostic conditions was central serous retinopathy (6%). This is the only group whose prognosis was probably the same in 1959 as today. (9) True, there are better diagnostic procedures available and laser treatment of the retinal leak is presently used, but, then as now, most of the cases healed without any treatment at all. The one central serous retinopathy case grounded in this study was severe enough to require laser treatment, which did not succeed, however, 89% of the subjects, seen were eventually returned to flying.

The remaining 22% of the cases consisted of miscellaneous diagnoses as shown in Tables 2 and 3, consisting of 18 different diagnostic entities. The ophthalmic diagnoses of the disqualified cases are shown in Table 4. Three of the 12 were disqualified for glaucoma, two had cataract complications, two had motility disorders, three had choroidal/retinal conditions, one had an optic nerve neuropathy and one had a corneal disorder due to herpes simplex.

CONCLUSIONS:

We see that only these 12 (8%) were disqualified for flying because of an ocular condition. 92% of these senior USAF aviators were eligible to be returned to full flight status from the opthalmologic standpoint, even though they had been diagnosed with significant ocular diseases. As we asked at the onset what would have happened to their flying career in 1959 as compared to today. All 149 subjects had successful correction of their presbyopia. This could also have been done 40 years ago

but the lenses and frames today are lighter and more compatible with the other equipment worn.

Forty years ago most of the glaucoma cases (Intraocular/hypertension had not as yet been diagnosed) would have been grounded. Over 90% of these now continue on to a full flying careers. In 1959 all aviators with cataracts would have been grounded-career ended. Today 94% of those seen in this study with an intraocular lens implant were returned to flying. 90% of the ocular motility/stereopsis cases were able to stay on flight status. Most of the cases in this study had mild to moderate keratoconus but with skillful use of optical and contact lens technology 100% were returned to full flight duties. Only one of the nine retinal detachment cases was unsuccessful so even with this serious ocular condition 89% of these senior USAF aviators returned to flying.

Senior military aviators can be afflicted with ocular conditions not much different from the younger aviator, except for the conditions of presbyopia, glaucoma/intraocular hypertension and cataracts. Fortunately for the present day senior aviator medical science and optical and ophthalmic technology advancements have made these conditions amenable to successful treatment or correction so that they no longer should be a cause of a shortened flying career, as they once were.

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INTRAOCULAR LENSES IN MILITARY AIRCREW

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Introduction

Modern advances in microsurgical procedures performed on the human eye distinctly stand out as one of the most, if not the most, dramatic advances in medical sciences over the last 75 years. Cataract surgery has emerged as one of the most common surgical procedures regardless of surgical subspecialty. Although attempts to "surgically" remove cataractous lenses can literally be traced back for thousands of years, visual rehabilitation postoperatively would not reach its zenith until development of the intraocular lens (IOL).

The human eye has two anatomical chambers: an anterior chamber (AC) filled with aqueous fluid between the cornea and the front surface of the lens and a posterior chamber (PC) behind the iris which contains the lens and vitreous (See Figure 1). An intracapsular cataract extraction (ICCE) involves removing the lens in total including its surrounding capsule. Therefore, an ICCE leaves behind no structural elements to support an intraocular lens (IOL) and involves a forward displacement of vitreous material to fill the space formerly occupied by the lens. This forward vitreous movement accounts for some of the increased risk for retinal detachment following an ICCE. Modern microsurgical advances have allowed removal of cataractous lens fibers from inside its capsular bag leaving the posterior capsular face intact and in place as a barrier to hold back the vitreous and a structural element upon which to place an intraocular lens. This type of procedure is called an extracapsular cataract extraction (ECCE) and represents the standard technique used around the world today. Keeping the posterior capsule intact prevents a significant movement of the vitreous forward and thereby reduces the risk of retinal detachment afterwards. The space left behind, formerly occupied by the lens, will be occupied by aqueous and provides the ideal location for an intraocular lens at the precise focal plane of the natural lens. An individual who does not have an IOL implanted is referred to as being *aphakic* while someone having an IOL implanted is regarded to be *pseudophakic*. Intraocular lenses can be implanted into either the anterior or posterior chambers, although by far the more common location today is in the posterior chamber (See Figure 2).

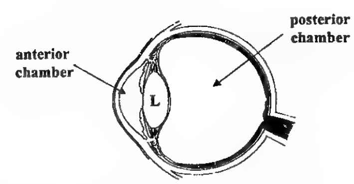

Figure 1: Chambers of the Eye

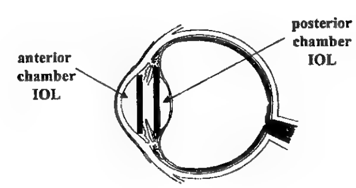

Figure 2: Potential IOL Location Planes

Spectacle eyewear following cataract surgery provided reasonable visual rehabilitation at the time, but the visual side

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effects from these very thick spectacles proved very challenging and limiting. With the development of contact lenses, both hard and soft, many of the undesirable optical consequences of thick spectacle lenses were greatly ameliorated. Contact lenses came much closer to replicating the natural optical state of the eye. However, these devices also suffered from some undesirable optical side effects, but in the aged, handling of these small, fragile devices proved a more significant impediment within the population most likely to require such surgery. Younger individuals, suffering from congenital, metabolic, or more typically, post traumatic cataracts, more easily adapted to contact lenses in most applications and environments.

However, the rigors and demands of certain vocational and occupational career fields, such as aviation, continued to pose complex challenges with even these highly successful optical appliances. The operational spectrum associated with modern military aviation environments, such as G forces, altitude and low humidity, coupled with unique and often hostile environmental extremes, posed a subset of problems that not even contact lenses completely solved. In addition, the critical visual demands of aircrew quickly identified a specialized subset that would benefit from reestablishing postoperative image quality that was as close as possible as those originally associated with the natural human lens. Consequently, development of a permanent optical device, an intraocular lens (IOL), that could be implanted within the eye itself as near as possible to the natural optical center of the eye's original lens, offered the greatest prospect to reestablish useful vision to as optically normal as possible. Today these tiny optical devices stand out within the world of ophthalmology, if not all of medicine, as probably the most singularly distinctive medical development of the last 75 years! But, intraocular lenses are more than just a development of a medical device; it is an ophthalmology story deeply rooted in aviation history itself.

Prior to the advent of contact lenses and intraocular lenses, the development of a cataract usually meant the functional end to a military aviator's active flying career. Thick aphakic spectacles induced image size variations between the two eyes that disrupted fusion and prevented stereopsis. Other disadvantages associated with such spectacles included their weight, which resulted in displacement under high $+G_z$, visual field size reductions, visual distortions, ring scotomas, and image magnification, all of which often led to significant perceptual problems. Therefore, prior to 1967, military aviators with advanced cataracts that significantly interfered with vision or aphakia, were grounded and no longer allowed to fly in military aircraft.

The use of contact lenses represented a major improvement in the optical correction of aphakia and an upturn in fortune for aviators. In 1967, the first aphakic USAF aircrew member was returned to limited flying duties following successful cataract extraction that was optically corrected with a hard contact lens.

Although, hard contact lens solved many of the optical and visual problems encountered with aphakic spectacles, including normalization of stereopsis, such lenses are susceptible to displacement under G loading due to their thickness and relative increased weight. Soon thereafter, the advent of soft contact lens materials ameliorated the G displacement problem and became the primary means for optical correction after cataract surgery until the mid 1970's.

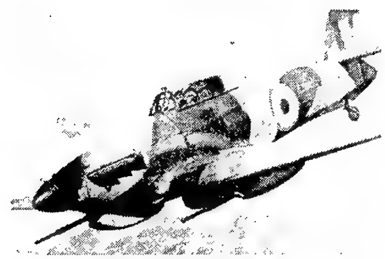
In 1979, the first USAF aviator was returned back to flying duties following a successful ICCE extracapsular and insertion of an anterior chamber intraocular lens. The decision to return this aviator to the cockpit was largely predicated on earlier research studies performed by the Ophthalmology Branch of the USAF School of Aerospace Medicine on rhesus monkeys who previously had had a variety of intraocular lenses implanted either into the anterior or posterior chamber of both eyes. After a suitable healing period (6 months), these monkeys were subjected to centrifuge rides up to $+12G_z$. Post-centrifuge slit lamp examinations failed to show any hemorrhages, displacement or dislocation of their intraocular lenses. The stability of tissue fixated IOLs under such G exposures demonstrated by this study resulted in a favorable waiver recommendation for such pseudophakic aircrew, providing other visual performance capabilities, such as visual acuity and stereopsis, met acceptable standards.

However, the road that finally culminated in these advanced aeromedical studies had its beginnings many years prior and was largely based on the clinical acumen of a single post-World War II ophthalmologist. In November of 1949, Dr. Harold Ridley, a British Ophthalmologist, inserted the first successful human IOL (See Figure 5).

Figure 3:

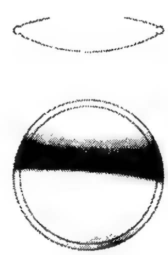
That first IOL was composed of Perspex CQ, polymethylmethacrylate (PMMA), a material that was identical to that used at the time in canopies and windscreens of common British WWII fighter aircraft, such as the Hurricane and Spitfire.

Figure 4:



Dr. Ridley had clinically managed and followed a number of British aircrew members who had sustained penetrating intraocular foreign bodies composed of canopy fragments received during combat. He was impressed with how stable and inert this material was regardless of where the fragment finally ended up resting in the eye. Dr. Ridley also considered another material at the time, glass, which was also a traditional well-known biologically inert material. This first IOL was a thick, round lens without fixation arms fabricated from a Perspex CQ button (See Figure 5).

Figure 5:

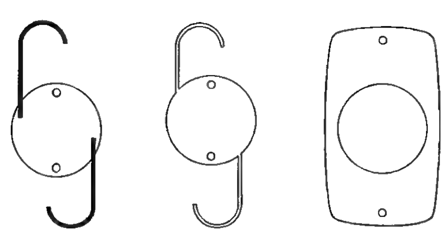


He surgically placed the lens into the posterior chamber on top of the vitreous face following an ICCE close to the plane of the natural human lens. He had previously concluded that the posterior chamber location would allow for the most natural

optics postoperatively. Unfortunately, the lack of fixation arms or haptics to anchor the lens at its location site by inducing fibrotic tissue reaction to fixate it and the fact that his first IOL was very thick and heavy, resulted in the lens displacing out of position and back into the vitreal cavity of the eye. Severe international professional criticism at the time from his colleagues suppressed further advances of the technology for nearly 30 years.

It wasn't until the early 1970's when a resurgence of interest in intraocular lenses reemerged. Intraocular lenses then developed rapidly and passed through considerable transitional alterations that witnessed their preferred insertion site within the eye moved from being clipped to the iris, to the anterior chamber, and then ultimately, and ironically, to the present preferred the plane of choice, namely within the residual capsular bag at the precise planer location of the natural human lens previously concluded to be the ideal site by Dr. Ridley. However, modern posterior chamber IOLs are extremely light in weight and usually have two polypropylene, polyethylene, or PMMA fixation arms, called haptics, to facilitate fixation and to secure them permanently in place (See Figure 6).

Figure 6: Basic Types of IOLs



Subjects

In 1979, a special USAF Aircrew Intraocular Lens Study Group was established at the Ophthalmology Branch of USAFSAM to evaluate and manage these aircrew for the duration of their careers. As of 1 July 1999, the USAF has 65 male aircrew members enrolled in this study, 44 from Active Duty and 21 from the Air Force Reserve (AFR) and Air National Guard (ANG). These 65 aircrew members have had cataract extractions, either ICCE or ECCE, with insertion of IOLs in a total of 80 eyes. Their overall mean age at the time of cataract surgery was 44 years. Active duty pilots ranged in age from 28-64, but on average were 43 years of age, while the AFR and ANG aviators were on average 45 years of age, with a range of 25-60 years.

Intraocular lenses were implanted into the anterior chambers in 4 eyes (5%) and into the posterior chamber in 76 eyes (95%). The IOLs were implanted only into the right eye in 27 (34%), left eye in 23 (28%) and bilaterally in 15 (38%). Of the total 80 eyes, 3 eyes had undergone ICCE (4%) while the vast majority of the eyes, 77 eyes (96%) had ECCE.

Of the 65 total aircrew members, 43 (66%) were pilots, 7 (11%) were navigators, 7(11%) were flight surgeons, and 8 (12%) occupied other ancillary crew positions.

The total accumulated flying hours for the pilots at the time of the surgery was 186,950 hours and individually ranged from a low of 1,000 hours to a high of 9,750 hours. Total flying hours for the navigators was 24,700 hours, with a range between 2,000 and 7,700 hours. Of the pilots, the type of aircraft category flown at the time of the surgery were: fighter-attack-reconnaissance (FAR) in 40%, tanker-transport-bomber (TTB) in 51%, and rotary wing in 9%.

Fifteen of the aircrew had bilateral IOLs: 6 pilots, 2 navigators, 4 flight surgeons, and 3 other crewmembers. Of the pilots with bilateral IOLs, 3 were in fighter aircraft, (T-33, F-15, F16, F-111F), 2 were in tanker-transport-bombers, and 1 in rotary wing aircraft.

The longest follow-up within the IOL Study Group has been for 12 years so far. As best that could be determined, the etiologies of the cataracts in USAF aircrew were: trauma in 17 (26%), associated with the family history of cataracts in 13 (20%), both trauma and family history in 3 (5%), associated with specific ocular cataract syndromes in 2 (3%), but could not be determined in 30 (46%).

Results

Seventy-eight eyes (97%) attained best-corrected visual acuity of at least 20/20 postoperatively and 62 eyes (77%) attained best-corrected visual acuities of 20/15. One pilot suffered traumatic retinopathy at the same time of his cataract and was only able to achieve a best-corrected postoperative visual acuity of 20/50. One pararescue technician also had an associated traumatic retinopathy with a best-corrected visual acuity of 20/40.

Sixty flyers (92%) passed stereopsis testing postoperatively, while 5 flyers (8%) failed stereopsis testing after surgery. Of those 5 flyers, 2 had preexisting microtropia and strabismus, 1 suffered traumatic pupillary dilatation (mydriasis) and also had an epiretinal membrane, 1 had a prior history of central serous chorioretinopathy which had caused a preoperative decrease in stereopsis, and 1 had an unexplained deterioration in stereopsis. Therefore, only 2 aviators appeared to have suffered a degradation in stereopsis after surgery.

Sixty-three flyers (97%) passed red-green color vision testing, while 2 flyers (3%) failed color vision testing postoperatively. Of those 2 flyers, 1 suffered traumatic cataract associated with an epiretinal membrane and 1 had a long-standing history of congenital red-green color deficiency.

We have had no IOL dislocations secondary to exposures related to the aerospace environment. But, we have had a dislocation of an IOL in one aviator postoperatively in a secondary implant (inserted as a second surgical procedure later after the initial cataract extraction) which dislocated slightly following sports trauma. The IOL movement was lateral and did not require surgical repositioning and he was eventually returned back to flying status although restricted from high-performance aircraft.

Aeromedical Recommendations

Fifty-nine out of 65 aircrew members (90%) initially received waiver recommendations and were ultimately waivered to return to flying. However, three flyers were grounded for ocular reasons: one was a flight surgeon who developed a retinal detachment following cataract surgery, one was a pilot with diminished stereopsis and visual acuity secondary to formation of an epiretinal membrane over his macula, and one was an ancillary crewmember who had longstanding substandard stereopsis and amblyopia. Three other flyers were grounded for non-ocular reasons that had developed concurrently with their ophthalmic condition: two pilots developed significant cardiopulmonary disease and one developed cardiovascular disease that prevented a favorable waiver recommendation in these crewmembers.

Surgical Recommendations for Aircrew

The current microsurgical procedure of choice in aircrew to remove a cataractous lens should involve an extracapular lens extraction and the insertion of a unifocal posterior chamber IOL. Whether to use phacoemulsification or suture versus sutureless techniques remain discretionary and individual surgeon decisions. The aim of the modern technique is to preserve the posterior lens capsule intact to allow support for insertion of the IOL into this capsular bag at the original plane of the natural lens. Should intraoperative complications occur, it is still possible for an anterior chamber IOL to be used and still salvage vision and the aviator's career.

The type of IOL to be inserted should involve a one piece PMMA lenticule, with haptics made of either polypropylene, polyethylene, or PMMA. These haptic materials are known to induce local tissue reaction that permanently fixes the IOL in place, a critical requirement for high performance flying. The size of the lenticule should be between 6-7 mm and positioning holes should be avoided if possible. The IOL material should contain UV blocking agents to protect the retina from UV and blue light phototoxicity after the natural lens has been removed. Multifocal lenses should not be allowed because of the overall degradation in visual quality associated with the relative blurring induced by such lenses.

Newer intraocular lens materials, such as silicone and acrylic lens, are also acceptable providing they are not the one-piece variety. Thus, silicone and acrylic lenses with either polyethylene, polypropylene, or PMMA haptices are acceptable since these haptices induce tissue reactions that will fixate these lenses adequately in place as well. However, one-piece (plate) silicone and acrylic lenses are relatively tissue inert materials that insight little to no tissue reaction in and of themselves. Clinical experience indicates that such lenses can spontaneously rotate and surgeons familiar with these materials can attest to the fact that these lenses can be removed easily from inside the posterior chamber, many years following original insertion because of this relative tissue inertness. The inability of these lenses to tissue fixate represent a contraindication for these materials in aircrew who are likely to experience vibrational and accelerative force extremes. However, it is also possible that in non-high performance aircraft, even the one-piece lens type may be considered, providing that such aircrew would not be eligible for more aggressive aircraft later on in their flying careers.

Following cataract extraction and IOL implantation, since the natural final UV filter, the lens, has been removed, it is extremely important that aircrew continue to be protected from phototoxic exposure for the duration of their flying careers. For this reason, aircrew should be fitted with additional UV blocking eyewear, i.e., UV 400 or similar, and should consider use of appropriate headgear to minimize sunlight exposure.

Aircrew who develop a cataract that requires extraction, should not be considered for return to the cockpit without comprehensive ophthalmological evaluation. They should be at least three months postoperatively, be stable clinically, and have stabilized refractions. All aircrew should be followed on an annual basis to ensure that they continue to meet standards and do not develop known post-cataract surgery complications.

Conclusion

By the creation of the USAF Aircrew Intraocular Lens Study Group, the USAF has accumulated a considerable amount of experience in the management of aircrew in all crew positions and in all aircraft types, following successful cataract surgery and implantation of intraocular lenses. Because such eyes have an increased risk for the development of other postoperative complications, such as retinal detachment, capsular opacification, membranes, and maculopathies, it is necessary that active aircrew members be reevaluated frequently to ensure that their visual performance remains compatible with acceptable vision standards and that no other complications arise that would be incompatible with flying safety and mission effectiveness.

We believe that this has been a highly successful program that has salvaged a considerable amount of aviation experience and has allowed valuable aircrew resources to return to the cockpit. Aircrew members in the Study Group have gone on to accumulate an additional 16,500 flying hours following their cataract extraction and IOL implantation. This figure signifies tremendous savings in both experience and training investments. To date, there have been no mishaps or accidents related to USAF aircrew with IOLs.

IOLs and their ability to correct the optical sequelae induced by removing the human lens remain one of the most notable medical achievements of our time. To fully appreciate the benefits of these appliances, one must consider that in our population, military aviators with very costly training and specialized skills have been fully rehabilitated and returned to the cockpit to fly our fastest and most complex aircraft.

Thanks to Dr. Harold Ridley, and many additional contributors along the way, microsurgical techniques and intraocular lenses have improved to the level where overall success rates, even to standards required in aircrew, remain quite high in competent hands. Almost poetically, nearly 50 years later, Dr. Harold Ridley finally received the international recognition he deserved from his colleagues for his outstanding contributions, not only to the visual rehabilitation of the civilian population, but as the USAF experience illustrates, preservation of valuable aviation resources and flying careers.

Thanks to the tremendous foresight of Dr. Harold Ridley, cataracts may no longer represent an irreversible career-ending development in an aircrew member. The use of modern IOLs has allowed over 90% of those aircrew members who have had cataract surgery to be returned back to the cockpit to a full military flying career. Today, IOLs have also even now found themselves successfully implanted into a NASA astronaut.

Visual Performance on the Small Letter Contrast Test: Effects of Aging, Low Luminance and Refractive Error

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Summary:
In this study the visual performance of aviators and a myopic, non-aviator group were compared to determine the effects of aging, available light and refractive error. The chart used is a novel chart called the Small Letter Contrast Test (SLCT) which measures sensitivity to contrast at the moderate to high end of the spatial frequency range near the visual acuity thresholds of most normal observers. All three variables influence visual performance on the SLCT, age having a greater effect on low luminance performance and refractive error having comparable effects on SLCT performance regardless of luminance level. High contrast visual acuity remains fairly stable and normal over the age range tested; however it decreases with increasing refractive error.

Introduction:
As the visual system ages there is a decrease in pupil size, an increase in intraocular scatter, and a decline in retinal function. How these changes affect routine daily activities does not generally become evident until well past age 60 even while standard measures of visual performance are still normal. Indeed, aging appears to have little impact on high contrast visual acuity (HCVA) until after age 70 (Haegerstrom-Portnoy, Schneck et al. 1999). The decline in HCVA after this age is generally minimal for normals who do not have age-related ocular changes such as cataracts or retinopathy, with the greatest decline between the ages of 80 and 100. Army aviators are therefore expected to have excellent HCVA, which should remain very stable over the course of a typical career.

Aviators have higher visual demands, however, and performance not measured by HCVA may be affected at a much earlier age. Visual demands in the army aviation environment include significant low contrast and low luminance scenarios that require excellent contrast sensitivity. Studies of the effects of aging on contrast sensitivity have shown a much earlier and more pronounced effect on this function than on HCVA (Owsley, Sekuler et al. 1981; Adams, Wong et al. 1988). A more sensitive measure of visual performance is needed to evaluate subtle visual changes that may affect function.

Another factor affecting performance may be refractive error. Although current standards limit the amount of refractive error for entry into aviation, many aviators develop ametropias during their careers. We were interested in whether low and moderate amounts of refractive error play a role in contrast sensitivity. Earlier studies of the contrast sensitivity function and refractive error have shown that high amounts of spectacle-corrected myopia (e.g. 8 or more diopters) will reduce sensitivity primarily at the higher spatial frequencies (Collins and Carney 1990; Risse, Saint-Blancat et al. 1996).

The purpose of this study was to evaluate the age-related visual performance changes of aviators and to compare these changes to a myopic, non-aviator population using a more sensitive measure of visual performance, the Small Letter Contrast Test (SLCT). The SLCT was developed in response to the need for a more sensitive measure of the visual capabilities of U.S. Army aviator candidates (Rabin 1995). The SLCT uses small 7.4 mm by 7.4 mm letters, equivalent to 20/25 (6/7.5) when presented at 4 meters, in lines of 10, each line decreasing by 0.1 log contrast level.

Rationale:
Operations in space and aviation require superior spatial vision to optimize target detection and obstacle avoidance. As aviators age, the ability to see under low luminance or other visually challenging conditions changes. The ability to adequately measure these changes and to apply appropriate physiological and technological

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counter-measures is critical to optimal performance.

Methods:
The aviation group consisted of 123 aviators and aircrew, ages 22 to 66, with minimal refractive error (0.00 ± 1.0 diopters). The non-aviation group consisted of 76 subjects, ages 22 to 63, with myopia (–6.25 ± 2.5 diopters). Visual performance was assessed using HCVA and contrast sensitivity using the SLCT. The SLCT was presented under two conditions, standard chart luminance of 100 cd/m^2 and low chart luminance achieved using neutral density filters placed in front of the eye for the aviator group and by decreasing chart luminance to 3 cd/m^2 for the non-aviator group. Separate investigators at different research facilities measured the two groups. Visual changes were evaluated in terms of age, luminance level and refractive error within each group and between groups.

Results and Discussion:

High Contrast Visual Acuity (Age)

Figure 1 shows the change in HCVA with age for both groups. Loss of high contrast acuity was minimal; less than 0.10 ± 0.08 logMAR loss (approximately 1 line) across the entire age range for both groups. The correlation coefficient for the regression was $r = 0.20$ for the aviator group and $r = 0.33$ for the non-aviator group. The difference between groups on the HCVA measure was statistically (0.04 logMAR, p=0.01), but not clinically significant (<1/2 line of acuity).

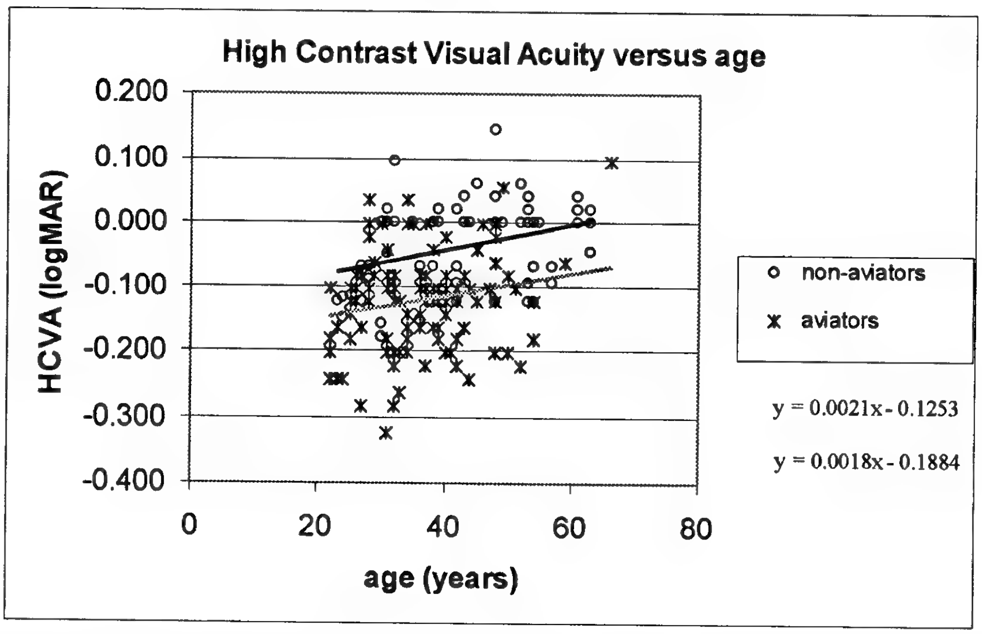

Figure 1: HCVA versus age. More positive values of HCVA (logMAR) indicate a decrease in performance. Regression equations are shown on the graph. The black line represents the non-aviator group and the gray line represents the aviator group. Note the range of performance across the entire age range as well as the overlap between the two groups.

Small Letter Contrast Test (Age and Luminance)

Figure 2 shows the change in SLCT performance under standard luminance conditions as a function of age for both groups. Contrast sensitivity on the SLCT decreased for the aviator group at a rate of 0.032 ± 0.04 logCS (almost 1/3 line) per 10 years under standard luminance conditions, while the decrease was slightly greater for the non-aviator group (0.043 ± 0.05 logCS per 10 years). The correlation coefficients for the linear regressions were $r = 0.15$ (aviator) and $r = 0.24$ (non-aviator). The difference in performance level between the two groups was statistically significant (0.11 ± 0.1 logCS, t=4.0, p<0.001), yet there is significant overlap between the groups, especially in the lower age groups.

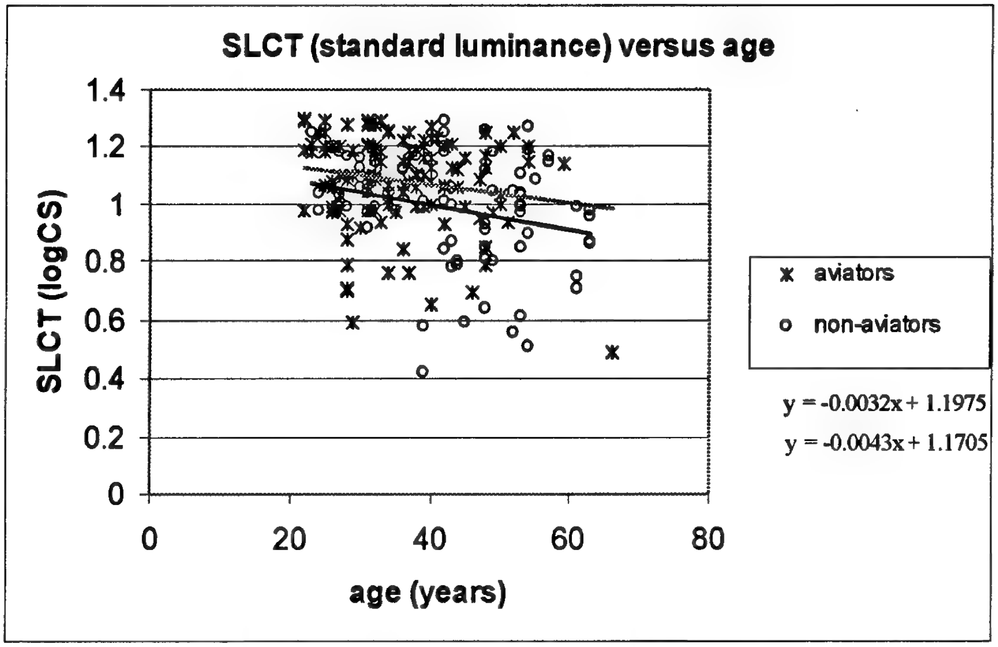

Figure 2: Small Letter Contrast Test performance under standard luminance conditions is plotted versus age. Regression equations are given on the graph. Regression lines are plotted (gray line = aviators, black line = non-aviators).

Figure 3 shows the low luminance SLCT performance with age. CS loss under these conditions was 0.06 ± 0.08 logCS per 10 years for both groups. The correlation coefficents for the regressions were $r = 0.31$ (aviators) and $r = 0.38$ (non-aviators). The difference in mean performance level for the two groups was 0.09 ± 0.11 logCS, which is statistically significant ($t=3.3$, $p<0.001$). The loss over the age range for both luminance levels was statistically ($p<0.001$) and clinically significant (1.5 to 2 lines at standard luminance and 2.5 lines at low luminance).

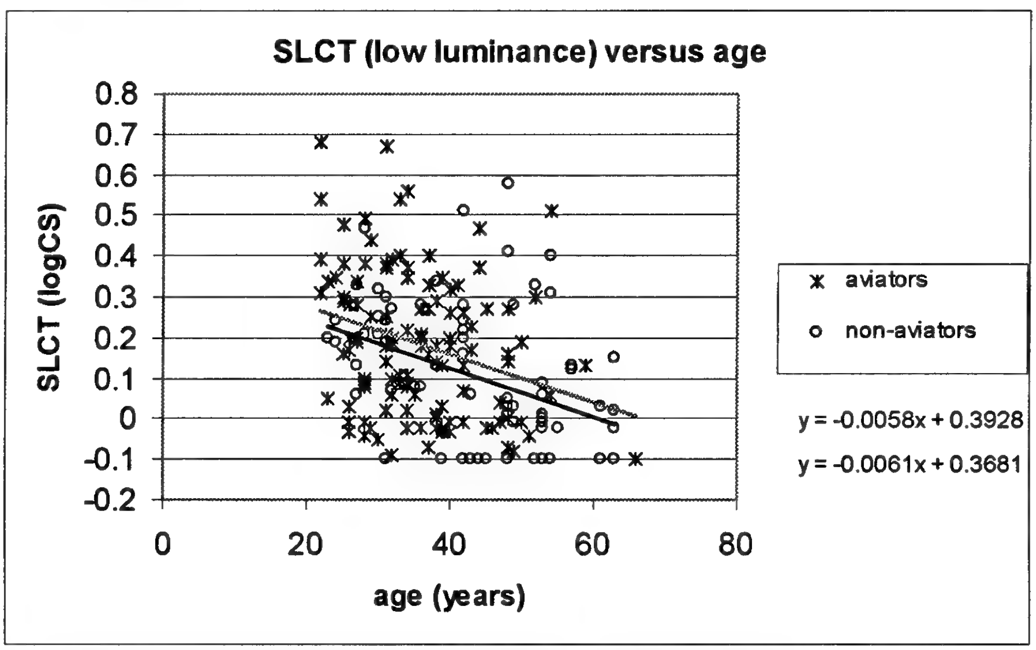

Figure 3: Small Letter Contrast Test performance under low luminance conditions is plotted versus age. Regression lines are plotted (gray line = aviators, black line = non-aviators).

Refractive Error

In Figure 4, performance on the SLCT is plotted as a function of refractive error. Figure 5 shows the effect of refractive error on HCVA. All three measures show a decrease with increasing refractive error. The regression correlations are stronger for the relationship between performance and refractive error than for performance and age. The correlation coefficients were $r = 0.40$ for standard luminance SLCT, $r = 0.30$ for low luminance SLCT and $r = 0.52$ for HCVA. Previous studies have shown that the optical effects of spectacles, specifically spectacle magnification (or minification, as in this case), are largely responsible for decreased visual performance of myopes (Collins and Carney 1990; Risse, Saint-Blancat et al. 1996). The aviators measured in this study were essentially emmetropic and are therefore massed near zero on the graphs, while the non-aviator group spans the range from –3.00 to –14.00 diopters of myopia.

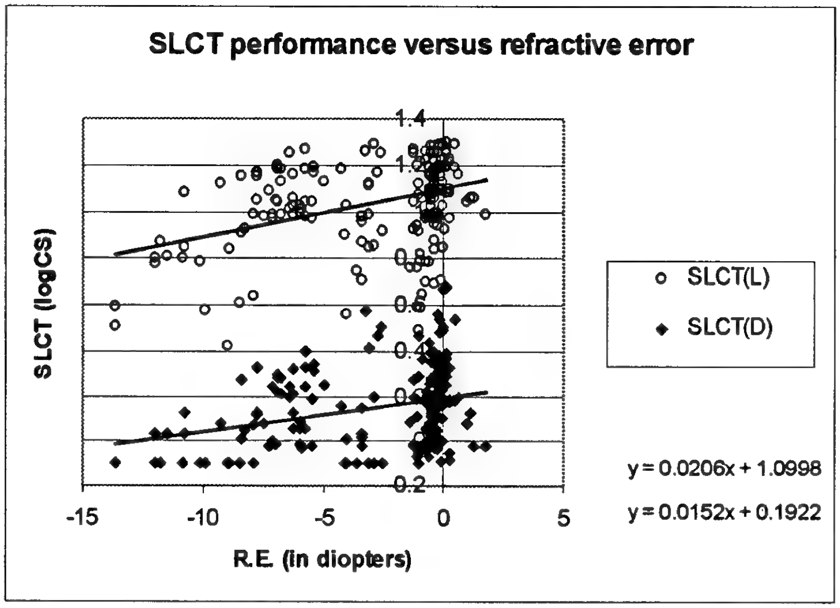

Figure 4: SLCT as a function of refractive error. Regression equations and plots given.

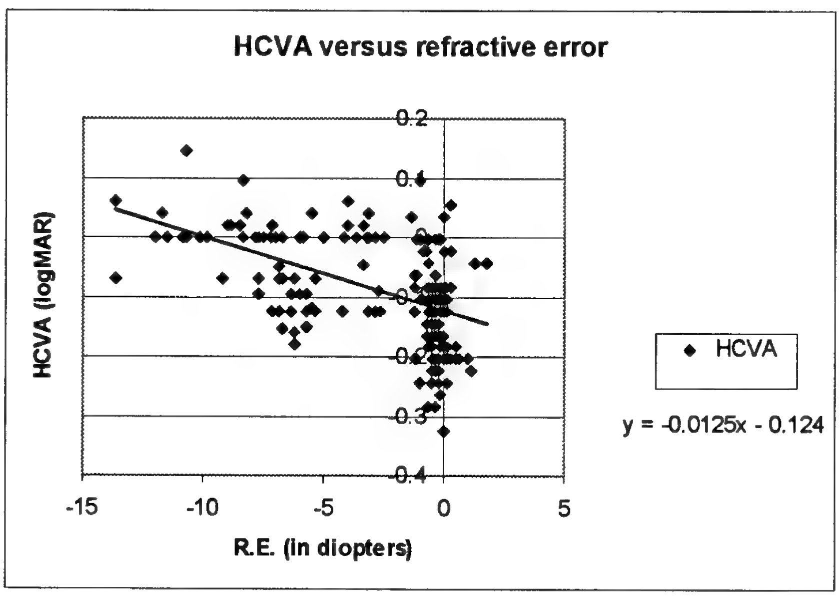

Figure 5: HCVA as a function of refractive error. Regression equation and plot given.

Aging *and* Refractive Error

Using multivariate regression and ANOVA, the effect of age and refractive error on visual performance was evaluated. The regression evaluations are presented in Table 1.

Table 1

Visual Measure	Regression equation	Correlation	ANOVA	Significance
HCVA	0.0022(age)-0.011(r.e.)-0.206	$R = 0.58$	F = 49.4	P < 0.0001
SLCT(standard)	-0.003(age)+0.018(r.e.)+1.22	$R = 0.44$	F = 22.6	P < 0.0001
SLCT(low)	-0.006(age)+0.010(r.e.)+0.40	$R = 0.44$	F = 22.4	P < 0.0001

Conclusions:

From the graphs it is evident that there is a relationship between aging and visual performance as well as refractive error and visual performance. Within each group and for each test there is a wide range of visual performance, however. Using age 40 as an example (see figures 1-3), HCVA ranged from –0.2 to 0.02 logMAR (more than 2 lines on the chart), SLCT standard luminance ranged from 0.65 to 1.25 logCS (6 lines) and SLCT low luminance ranged from –0.1 to 0.35 (4.5 lines). In terms of the significance of measurable changes in vision, HCVA remained within an acceptable range over the age and refractive error of both groups, while more significant decreases in vision were measured on the SLCT, especially after age 40 and above 8 diopters of myopia.

The SLCT is able to detect more significant changes in visual performance with age, refractive error and luminance than high contrast acuity tests. Contrast sensitivity is lower among myopes and under low luminance conditions and it decreases with age. The difference between contrast sensitivity under standard and low luminance conditions also increases with age; indicating aging changes in the visual system will more significantly affect performance under low light conditions. Testing pilot visual performance beyond high contrast will reveal limitations, which may be addressed through improved lighting, instrumentation, sighting devices and cockpit configuration.

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Cockpits modernes : Comment rester performant au fil des ans ?

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Résumé

Les altérations des fonctions perceptives et cognitives survenant avec l'âge interfèrent avec les processus de prise et traitement de l'information mis en jeu par les personnels navigants au cours du vol. L'expertise parallèlement développée par les opérateurs du fait de l'entraînement aux missions limite le retentissement opérationnel de ces altérations fonctionnelles. La compensation liée à l'expertise peut cependant être mise en défaut. Un accompagnement des opérateurs s'avère donc nécessaire, au niveau de la formation et de la mise en œuvre des personnels, d'une part, au niveau de la présentation de l'information, d'autre part, en prenant en compte l'évolutivité des seuils. Une interface adaptative peut être une solution proposée.

Abstract

Perceptual and cognitive capacities decrease due to aging can affect pilots'efficiency in flight.. Pilots' expertise simultaneously improves as training is performed. This expertise tends to counterblance functional impairements. To further keep aging effects in check, specific training and pilot management on one hand, cockpit design on the other hand must be implemented. At the cockpit display level, an adaptive interface is a relevant suggestion.

Introduction

Si l'on ne peut prédire un brillant avenir au membre d'équipage qui anticipe sur la situation et fait corps avec son système piloté, tout au moins le pilote qui court après les événements qui se déroulent, celui qui n'est pas dans la boucle, est-il promis à un avenir plus qu'incertain. Cet adage partagé par la communauté aéronautique est encore moins contestable lorsque l'on considère l'aéronautique de défense.

Le personnel navigant doit à chaque instant tirer le meilleur parti de son système, intégrer les changements de son environnement hautement évolutif, guetter les moindres indices des acteurs du théâtre d'intervention pour les interpréter dans un modèle adapté de la situation opérationnelle (Menu et Amalberti, 1990).

L'avancée en âge des personnels navigants a un certain nombre de répercussions sur ces mécanismes de prise et traitement de l'information alimentant les processus de prise de décision.

D'un point de vue ergonomique, la question peut être envisagée sous l'angle des adaptations de l'interface homme-système qui faciliteraient le maintien de la performance opérationnelle en dépit des effets de l'âge sur les personnels.

1- Traits dominants de l'activité en vol

Les mécanismes de traitement de l'information impliqués dans le contrôle de l'activité en vol reposent sur la confrontation des informations sur la situation en cours, issues des processus sensoriels, et de prédictions sur la planification du vol (Brainbridge, 1999).

Les informations d'état sur l'environnement intérieur et extérieur à la cabine de pilotage sont analysées par nos différents capteurs sensoriels, en fonction de leur domaine de sensibilité (ou bande passante). Le poids accordé aux différentes modalités sensorielles (vision, audition, système vestibulaire, proprioception, odorat, ...) peut varier en fonction des mécanismes attentionnels du sujet. L'intégration de ces données sensorielles participe à mettre à jour la représentation de la situation du personnel navigant. Dans un second temps, celui-ci devra éventuellement la partager avec d'autres acteurs selon la taille de l'équipage et celle de la formation engagée dans la mission.

Un élément majeur est le rôle joué par la représentation de la situation sur la conduite de l'activité du pilote. En alimentant la mémoire de travail, elle conforte le pilote dans le bon déroulement de la mission, validant ainsi le modèle de contrôle de processus de notre acteur (la mission se déroule comme prévu), ou au contraire, la représentation de la situation peut mettre en avant les traits saillants d'une évolution de la situation non conforme au déroulement nominal, signalant une des multiples variantes du processus contrôlé, cette variante

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appartenant , selon les cas, plus ou moins au domaine connu du pilote.

Deux caractéristiques majeures de l'activité en vol sont ainsi mises en exergue :

- L'activité est programmée, anticipée, analysée ;
- elle s'effectue dans le cadre d'une contrainte temporelle incontournable.

En effet, une mission est le déroulement en temps réel d'une activité définie en phase de préparation de mission, avec son mode nominal et ses variantes, chaque phase s'inscrivant dans des créneaux temporels stricts.

À la première analyse " bottom-up " (i.e. de la périphérie vers les structures centrales en une démarche intégrative), peut être substituée une approche " top-down " où le pilote, à chaque instant de sa mission, déroule un enchaînement de procédures élémentaires conforme à l'anticipation sur l'activité qu'il avait élaborée en préparation de mission. Cet enchaînement de procédures élémentaires constitue ce qu'il convient d'appeler " un schéma d'activité " caractéristique de chaque phase de vol.

Ces schémas s'établissent et se confortent au cours de l'entraînement par l'exposition répétée à des phases de vol comportant un certain degré de communalité (Hoc, 1987). Avec la répétition de phases de vol de même nature, le pilote organise son activité selon un certain enchaînement logique de procédures élémentaires. Tout d'abord stabilisés pour une situation nominale (i.e. pour un déroulement normal de la mission), les schémas s'enrichissent progressivement d'alternatives pour lesquelles des procédures adaptées permettent la poursuite du contrôle de l'activité en conservant un coût cognitif acceptable. Annexés au schéma de base, figurent un certain nombre d'incidents potentiels et à chaque incident correspond un enchaînement de procédures élémentaires appropriées. La réaction est immédiate. Le diagnostic et le traitement de l'incident sont effectués avec un minimum de ressources cognitives.

Dans la mémoire de travail, les informations sensorielles permettent l'instanciation de ces schémas, phénomène par lequel une procédure élémentaire est reconnue comme achevée, autorisant la procédure élémentaire suivante, dans le schéma en cours, à être mise en œuvre. La recherche d'indices dans l'environnement, dans l'étendue des informations sensorielles disponibles, apparaît alors comme une démarche active et sélective. Le pilote recherche l'information qui valide l'action en cours pour poursuivre son activité, éventuellement, la modifier. Cette approche a de sérieuses implications en termes de conception d'interface lorsqu'il s'agit de prendre en compte la variabilité inter-opérateurs liée à l'âge.

2- Évolution des capacités sensori-cognitives avec l'âge

Les modifications des capacités élémentaires de prise et traitement de l'information avec l'âge des intéressés ont été largement étudiées. L'ensemble des travaux démontre une altération progressive des performances (Tsang, 1992, for a review).

Deux particularités apparaissent plus saillantes dans l'ensemble de ces données expérimentales.

- Tout d'abord, la tendance évolutive est toujours homogène quel que soit le critère considéré, les capacités se dégradant avec l'âge. Si l'on se limite aux caractéristiques qui sont les plus critiques dans le contrôle de l'activité en vol, on constate : i) du point de vue perceptif, une élévation des seuils de détection et de discrimination ; ii) du point de vue cognitif, des difficultés croissantes de récupération des informations stockées en mémoire, mais aussi des difficultés d'apprentissage étroitement liées aux problèmes de mémorisation, un ralentissement dans les tâches de résolution de problème exacerbé lorsque l'activité comporte un choix ou la confrontation d'indices dispersés dans l'environnement, enfin une altération de la coordination psychomotrice particulièrement marquée dans le contrôle impliquant de façon dysymétrique différents segments corporels.
- Le second aspect majeur est l'extraordinaire variabilité inter-individuelle des effets de l'âge. En conséquence, dans chaque fonction élémentaire, on peut identifier des sous-groupes d'individus aux âges les plus avancés de l'échantillon dont les capacités dépassent celles des adultes jeunes correspondant généralement aux capacités maximales.

Toujours est-il qu'une dégradation relativement systématique de ces capacités élémentaires, déterminantes dans l'activité de pilotage, ne peut laisser présager que la survenue de problèmes dans la compatibilité de l'âge avec la performance opérationnelle.

3- Développement de l'expertise

En fait, si l'on considère l'évolution de la performance avec l'âge, il faut également prendre en compte qu'en parallèle se développe le niveau d'expertise du personnel navigant. En effet,

l'entraînement et la pratique du vol améliorent progressivement les mécanismes de contrôle de l'activité.
L'exposition répétée à des situations génériques permet d'obtenir des schémas de plus en plus raffinés, dont les procédures élémentaires sont de plus en plus précisément ciblées et leur instanciation est obtenue par la prise d'informations de plus en plus spécifiques. Cette relative automatisation de l'activité épargne ainsi des ressources cognitives qui peuvent être dédiées à la gestion à long terme de la mission, favorisant encore l'anticipation.

Une plus large gamme d'événements intercurrents, associés à des procédures alternatives, est progressivement associée au schéma nominal et des procédures expérimentées sont également validées comme solution de recours en cas d'incident. Cet aspect est primordial puisqu'il raccourcit le temps de résolution de problème en condition incidentelle, soulageant la pression temporelle systématiquement accrue en pareilles circonstances. Enfin, on assiste à un ajustement des procédures opératives des sujets experts pour compenser la dégradation des capacités perceptives ou cognitives élémentaires. Connaissant ses limites, l'expert adapte son savoir-faire ou choisit des informations signifiantes compatibles avec son handicap pour maintenir la performance globale.

À ce stade, il serait tentant de conclure que l'adaptation comportementale liée à l'expertise permet de compenser les altérations des capacités physiologiques et cognitives liées à l'âge.

Le tableau n'est pas toujours aussi simple et certaines circonstances peuvent mettre en défaut les mécanismes d'adaptation liés à l'expertise.

- Tout d'abord, une partie de l'information risque effectivement d'être perdue. Notamment, si elle ne s'intègre pas directement dans le cadre des schémas d'activité, sa prise en compte risque d'être abusivement retardée.
- La seconde faille majeure est représentée par le cas des sauts technologiques dans le système que le pilote doit contrôler et pour lequel son niveau d'expertise s'avère inadapté. Le saut technologique le plus récent –et peut-être le plus important d'un point de vue facteur humain que l'aéronautique ait présenté- fut la génération des aéronefs qui ont associé d'emblée un glass cockpit avec son information évolutive, un contrôle de trajectoire par commandes de vol électriques mettant au second plan la notion de domaine de vol, et un haut degré d'automatisme dans le contrôle des systèmes.

Cependant, si l'on considère la fréquence d'impact de ces deux sources de problèmes, apparaît un déséquilibre flagrant. L'adaptation au saut technologique a largement alimenté la littérature, elle constitue un domaine théorique à part entière mais elle se fait, dans la majorité des cas, sans heurt, tandis que le défaut d'accès à l'information par déficit perceptif est le pain quotidien des personnels navigants. Il est alors licite de rechercher si les cockpits actuels présentent toutes les ressources compensatrices disponibles à l'heure actuelle pour minimiser l'impact des altérations perceptives sur le contrôle de l'activité.

4- Accompagnement des opérateurs

4-1- Adaptation au saut technologique

Les conséquences de l'introduction d'un saut technologique dans l'environnement de travail, pour spectaculaires qu'elles soient, restent limitées dans le temps. Si l'on considère, par exemple, le décours temporel des transformations d'équipages sur avion de nouvelle génération dans le cas du M2000, pour l'armée de l'Air française, le délai qui sépare l'introduction de l'avion dans les Forces de la transformation du dernier escadron, se limite à une période de 7 ans.
Dans cette période transitoire, différentes actions d'intervention peuvent être suggérées.

En ce qui concerne les aspects techniques, on peut agir au stade de la formation en mettant en exergue d'une part, les domaines de recouvrement autorisant un transfert de connaissances positif entre le système traditionnel et le nouveau système, et d'autre part, les domaines spécifiques nécessitant le développement de procédures de contrôle dédiées. Au-delà de l'entraînement en conditions réelles qui va permettre l'ancrage des schémas nominaux, l'entraînement en simulateur s'attache à l'enrichissement des connaissances procédurales en condition critique. La situation critique est par essence rare en vol réel mais, dans ce cas, une réaction adaptée doit être en adéquation avec la forte contrainte temporelle.

En marge des compétences techniques, la constitution d'équipages d'âges mixtes permet de minimiser les effets de transfert de procédures inadaptées par les experts formés sur les anciens systèmes grâce à la démarche inculquée *de novo* au personnel nouvellement formé. L'impact de ces équipages mixtes sur la sécurité peut être réel. L'efficacité des équipages mixtes est rendue possible par la démarche de " Crew Resource Management " (CRM)

développée de façon relativement généralisée et qui commence à porter ses fruits. La formation CRM introduit une prise de conscience par le personnel navigant de la fluctuation dans le temps de ses capacités psycho-physiologiques, et cognitives. L'accent est mis sur le fait que la performance peut, en retour, être optimisée à l'échelon d'un équipage.
Enfin, il ne faut pas négliger l'importance de l'approche personnalisée qui est du ressort de la gestion des ressources humaines et vise à identifier les sujets qu'il serait dangereux de transformer coûte que coûte, comme les experts ayant un trop long passé sur technologie classique et dont les capacités d'adaptation ne permettront jamais d'atteindre un niveau de performance acceptable sur les nouveaux équipements.

4-2- Prise en compte des altérations perceptives

La philosophie d'approche de la compensation des altérations perceptives au niveau de l'environnement de travail peut se décliner en 2 niveaux: la première option concerne une augmentation des marges perceptives pour que les acteurs les plus âgés aient aussi accès à l'information ; la solution alternative consiste à concevoir un cockpit qui s'adapte aux capacités perceptives de son utilisateur.
Augmenter les marges perceptives, c'est utiliser les seuils des sujets les plus âgés pour définir les normes de présentation de l'information. C'est une action qui se mène au stade de la conception des interfaces. L'information sera donc accessible à tous, même si elle est fortement supra-liminaire pour les plus jeunes.

Si l'on considère, par exemple, la capacité de détection du contraste, exprimée par la courbe de sensibilité au contraste, pour différents groupes d'âges, les capacités de détection se réduisent progressivement au fur et à mesure que les sujets vieillissent (Owsley et al., 1983). Lorsque la courbe s'abaisse, la zone des contrastes perceptibles, située au-dessous de la courbe, se réduit tandis que les contrastes non perceptibles par l'observateur, inclus dans la zone située au-dessus de la courbe, sont de plus en plus nombreux. En choisissant de présenter une information dont le contraste correspond à une valeur située sous la courbe la plus pénalisante, l'ensemble des utilisateurs a accès à l'information.
Une telle démarche peut être étendue à la plupart des seuils perceptifs et aux principes de codage de l'information dans les cockpits. À titre d'exemple, la taille des symboles pourrait être augmentée pour solliciter la discrimination de détails à un niveau encore plus éloigné de l'acuité visuelle. Ou encore, la prise en compte de la plus grande susceptibilité à l'éblouissement avec l'âge pourrait conduire à traiter les reflets de façon plus systématique dans les cockpits et à augmenter le contraste entre les symboles et leur fond pour qu'ils restent perçus dans les conditions éblouissantes de la haute altitude.

Le second mode d'intervention est de concevoir un cockpit adaptatif. Ce concept permet de prendre en compte la variabilité inter-individuelle des utilisateurs. Il s'inspire directement du Glass cockpit lequel réalise un véritable cockpit adaptatif sur le plan cognitif, l'information étant modulable en fonction du besoin du pilote et de la phase de vol. Il s'agit donc ici de transposer le concept dans le domaine perceptif. Dans ce concept, l'adaptation se fait en ligne, en fonction de la stimulation concernée et pour garantir son pouvoir informationnel à l'utilisateur.

Prenons le cas de la perception des contrastes. Les techniques d'analyse d'image permettent actuellement de renforcer les contrastes d'une image pour une taille de détails voulue. Des détails inaccessibles à la perception compte tenu de leur contraste dans l'image initiale peuvent, après renforcement sélectif, devenir détectables. Des formes déterminantes pour le contrôle de la trajectoire à court ou moyen terme peuvent ainsi être identifiées dans l'espace survolé et permettre l'anticipation du pilote sur le contrôle de son activité. Prenant en compte les besoins perceptifs de l'usager, l'interface se transforme pour rendre l'information qu'elle contient accessible au pilote.

Ce même principe peut être appliqué au domaine auditif, par exemple, où la réduction active de bruit, appliquée pour neutraliser le niveau sonore de l'environnement, permet d'améliorer le rapport signal sur bruit des communications vocales et améliorer leur intelligibilité qui est particulièrement dégradée avec l'âge (Bergman et al., 1976).

Enfin, on peut envisager une redondance des informations selon plusieurs modalités sensorielles pour agir par synergie intersensorielle.

Plusieurs degrés d'adaptabilité de l'interface peuvent être considérés selon que l'utilisateur configure lui-même son interface en sélectionnant les fonctionnalités d'aide à la perception qu'il désire, ou selon que l'interface adapte d'elle-même la présentation de l'information en fonction de la stimulation et de la réponse du personnel navigant au cours de la présentation ou en intégrant les réponses antérieures à une simulation comparable.

Conclusion

La prise en compte des altérations dans les capacités de prise et traitement d'information liées à l'âge et de leurs conséquences sur le contrôle de l'activité en vol, permet de pointer la grande marge de manœuvre qu'il reste pour améliorer la prise d'information dans les cockpits grâce à l'adaptation de la présentation de l'information aux capacités perceptives des pilotes. Si le pilote peut utiliser son intelligence d'être humain, sa flexibilité cognitive pour remodeler ses schémas de contrôle de l'activité en fonction de son âge et de son niveau d'expertise, il est entièrement dépendant de ses capacités de prise de l'information. Adapter la présentation de l'information à la bande passante des capteurs sensoriels de l'utilisateur est un objectif qui peut être atteint.

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14. Abstract

In downsizing militaries with aging populations, the current and projected scarce resources, increasing costs of training and the significant experience (also at significant cost) of aging crewmembers makes aging crewmembers an increasingly valued commodity, particularly in militaries of the future. Experience, wisdom, healthy lifestyles and medical and technological advances seem to compensate to some extent for actual or presumed decreased performance and other adverse effects of aging (physical, physiological, psychological) in many crewmembers. Most "aging" studies and data, however, were on general (civilian) populations. Available data on the performance of aging crewmembers in stressful military environments have not been previously summarized and presented on any large scale. Military age policies (pilots, special crew, etc.) of several countries were collected in advance for presentation and discussion, and the NATO Human Factors and Medicine Symposium on "Operational Issues of Aging Crewmembers" was held in Toulon, France 11-14 October 1999. There were two keynote speaker presentations and 32 papers presented to the 120 participants registered for the symposium. The broad aspects of this topic were divided into three Sessions, including 12 papers on "Operational Aspects of Aging Crewmembers", 8 papers on "Aging Crewmembers: Psychological and Cognitive Performance Implications", and 12 papers on "Physiological and Sensory Aspects of Aging". Speakers presented data on a wide variety of effects on aging, including the effects of G forces, jet lag, spinal disease, ECG findings during centrifuge training, hypoxia tolerance and pulmonary function (in older divers), sleep, working memory, risk taking, cognitive and sensory limitations, personality and behavior, neuropsychiatric referrals, anthrax immunization, growth hormone, endocrine response to training, autonomic cardiovascular control, biochemical-metabolic indices, endothelial dysfunction, intima media thickness, cardiovascular risk factors, ocular problems and intra-ocular lenses, small letter contrast tests and modern cockpits. There was a notable lack of data on women crewmembers and this data needs to be obtained whenever possible during future studies of aging crewmembers. One could conclude from the data available so far that: (a) During these times of prevention, health promotion and healthy lifestyles, physiologic age of individuals seems to be more important than chronological age of groups; (b) Knowledge, behavior and experience seem to adequately compensate for aging crewmembers in military environments; and, (c) The above, combined with new medical and surgical therapies and technological advances (in equipment designs, etc.), appear to justify seriously re-looking at current age policies for military crewmembers (particularly if, and when, a country's military manpower and budget projections deem it appropriate).

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